ISSN 1349-113X
JAXA-SP-07-017

宇宙航空研究開発機構特別資料
JAXA Special Publication

第20回 マイクロエレクトロニクスワークショップ

THE 20th MICROELECTRONICS WORKSHOP

<MEWS-20>

民生用部品・材料・技術の宇宙転用の現状と今後

平成20年2月

宇宙航空研究開発機構
Japan Aerospace Exploration Agency

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総合技術研究本部

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1．開催趣旨

JAXA は、宇宙用電子部品・材料及び機構部品の開発や調達に関して、世界の動向を注視しながら、我が国が進むべき方向、更に我が国に整備すべき宇宙用部品・材料技術を探るために、内外の宇宙機関、システムメーカ、部品メーカ及び部品輸入商社などの広範囲の参加を得て、年度毎にふさわしいテーマを選び、活発に討議し、意見や情報の交換を行うことを目的にマイクロエレクトロニクスワークショップ（Microelectronics Workshop：略称 MEWS）を毎年開催しています。

またこのワークショップに併設して、国内外の企業による部品展示も行っております。この部品展示会は、部品メーカが内外のシステムメーカ参加者に直接その技術力をアピールしたり、具体的な商談のできる場であると同時に、ユーザーの要望を聞き、新製品開発・性能改善のきっかけの場となっています。一方、システムメーカは一同に会した宇宙用部品メーカ及び関連輸入商社等から最新の情報を得ると同時に、部品メーカに対する要望を投げかける場となり、部品メーカ、システムメーカ双方の情報交換の場として利用されています。

第 20 回マイクロエレクトロニクスワークショップ（以下、MEWS-20）は平成 19 年 10 月 29 日から 30 日にかけて、つくば国際会議場（エポカルつくば）において、開催されました。

MEWS-20 はそのメインテーマを「民生用部品・材料・技術の宇宙転用の現状と今後」とし、海外の宇宙機関 NASA、ESA、DLR の部品部門の代表者及び DGA の信頼性工学の代表者から、各機関の宇宙用部品の技術開発状況や部品調達プログラムの状況や問題点、信頼性予測などの報告をしていただきました。

さらに特別講演として、日産自動車（株）殿から自社製品における品質マネージメントについて、また、経済産業省殿から我が国における民生部品・技術政策と即応型宇宙システムの構築について講演していただき、好評を博しました。

国内部品メーカ及び JAXA 職員による開発成果、開発状況などの論文発表も行われたことは言うまでもありません。詳細は次ページ以降に掲載する発表資料をご覧ください。

また、宇宙用部品展示会においては、昨年の MEWS-19 に引き続き、「MEMS＆ナノテク関連展示会」を併設いたしました。 MEWS-21 以降もこの流れをさらに発展させ、宇宙用部品・材料・機構技術へのMEMS＆ナノテク関連技術の取り込み、実用化へ努力していきます。

このような活動がこれからの日本の宇宙開発の基盤を支えるものとして少しでもお役に立てれば幸いです。

NASA　：　National Aeronautics and Space Administration
ESA　：　European Space Agency
DLR　：　German Aerospace Center
DGA　：　French Ministry of Defense
MEMS　：　Micro Electro Mechanical Systems

2. プログラム

（敬称略）

■ ワークショップ第1日 【中ホール200】 平成19年10月29日（月）10:00～16:00

時刻	プログラム項目	【発表者氏名・所属】 論文名
10:00-10:05	開会挨拶	【坂田 公夫・JAXA】
10:00-10:25	基調講演	【山本 昭男・JAXA】 総合技術研究本部での宇宙基盤技術における研究開発
10:25-11:05	招待講演-1	【北澤 宏・日産自動車株式会社 市場品質改善グループ】 日産自動車における品質マネジメント
11:05-11:25	特別講演-1	【佐伯 徳彦・経済産業省 製造産業局 航空機武器宇宙産業課 宇宙産業室】 我が国における民生部品・技術政策と即応型宇宙システム （Space on Demand）の構築
11:25-12:05	特別講演-2	【秋山 雅胤・財団法人 無人宇宙実験システム研究開発機構 技術本部 研究開発第二部】 SERVISプロジェクトにおける民生部品評価
12:05-12:05	連絡事項	【事務局】
12:05-13:35	昼食	昼食
13:35-14:00	海外招待者講演(米)-1	【Jeffrey H Sokol・The Aerospace Corporation】 Hybrid Microcircuit Inherent Reliability for Space Applications
14:00-14:25	海外招待者講演(欧)-1	【Franck DAVENEL・DGA】 Experimentation of the new reliability prediction method FIDES
14:25-14:50	海外招待者講演(欧)-2	【Jurgew Tetzlaff・DLR, Quality and Productassurance】 DLR Assessment Procedure of Commercial Parts for Space Use and First Experiences.
14:50-15:15	メーカ講演-1	【Geoffrey Penhaligon・IGG Component Technology Ltd. 】 Using commercial parts, understanding the risks and associated mitigating actions
15:15-15:35	JAXA報告-1	【吉川 健太郎 JAXA産学官連携部】 JAXA産学官連携施策について
15:35-15:35	連絡事項	【事務局】
15:35-18:00	部品展示会	＜部品展示会会場（中会議室202）＞
18:00-20:00	懇親会	＜懇親会会場（大会議室101）＞

（敬称略）

■ ワークショップ第2日 【中ホール200】 平成19年10月30日（火）9:30～16:00

時刻	プログラム項目	【発表者氏名・所属】 論文名
9:30-10:10	特別講演-3	【三田 信・JAXA 宇宙科学研究本部 宇宙探査工学研究系】 宇宙用MEMSデバイスの可能性
10:10-10:30	JAXA報告-2	【荒川 哲人・JAXA総合技術研究本部 部品・材料・機構技術グループ】 MEMS部品の宇宙適用に関する検討
10:30-10:50	招待講演-2	【蕨本 直伸・三菱電機株式会社】 衛星搭載部品の課題と将来展望
10:50-11:10	メーカ講演-2	【立山科学工業株式会社】 宇宙開発用信頼性保証チップ形皮膜抵抗器 JAXA CRK16H, 10H, 8H, 4H, 2H
11:10-11:35	海外招待者講演(欧)-3	【Andrew Robert Barnes・ESA/ESTEC/TEC-QCT】 Overview of GaN microwave component development activities at ESA
11:35-11:55	JAXA報告-3	【新藤 浩之・JAXA総合技術研究本部 部品・材料・機構技術グループ】 SOI ASIC/FPGAの開発状況
11:55-11:55	連絡事項	【事務局】
11:55-13:25	昼食	昼食
13:25-13:50	メーカ講演-3	【久野 真一・Aeroflex Colorado Springs, Inc.】 Radiation Hardened 350nm Triple-Well Mixed-Signal ASIC Technology
13:50-14:10	メーカ講演-4	【松井 崇雄・三菱電機株式会社】 低衝撃保持解放機構の開発
14:10-14:35	海外招待者講演(米)-2	【Michael J Sampson・NASA EEE Parts and Packaging (NEPP) Program】 The Development of a NASA Lead-free Policy for Electronics
14:35-15:05	特別講演-4	【山本 克己・テクノオフィスヤマモト】 日本の鉛フリー化の状況
15:05-15:25	JAXA報告-4	【根本 規生・JAXA安全・信頼性推進部】 JAXAにおけるRoHS問題の取り組みと錫ウィスカの基礎評価
15:25-15:40	総合質問	【事務局】
15:40-15:55	まとめ講演	【田村 高志・JAXA総合技術研究本部 部品・材料・機構技術グループ 】
15:55-16:00	閉会挨拶	【田村 高志・JAXA総合技術研究本部 部品・材料・機構技術グループ 】

3. 開会挨拶

坂田　公夫　宇宙航空研究開発機構（JAXA）理事、総合技術研究本部　本部長

（要旨）

このワークショップも今年で20回目を数えるにいたりました。このように進められてきたのも皆様のおかげと感謝しております。

今年のワークショップは民生用部品などの宇宙転用という主題です。我々の宇宙開発においては部品、コンポーネントについていくつかの課題を持っております。これは世界が共有する問題でもあります。技術的あるいは調達面での課題について、民生用の部品、コンポーネントが解決の一端を提供していただけるのではないかと期待しています。

また本日は日産自動車、経済産業省から招待講演を頂きます。ここでも同様の趣旨で、品質保証等の課題を議論いただけるものと思います。

我々は次世代の宇宙開発に向けてさまざまな領域で努力していますが、技術、部品、コンポーネントの分野で常に世界と問題を共有しながら進んでいきたいと思っています。このワークショップが昨年からナノテクノロジーも含めて幅広くそのようなスタディを始めたのも、また、今年は会場をここ国際会議場に移し広く皆様の参加がいただけるように、また展示も多く提供できるように致しましたのも、その輪を広げたいという思いからです。

本日、明日の議論を通して問題の共有と解決への道筋、展望が開ければ幸いです。この会議を通して活発な議論、活発な人的交流をしていただいて、皆様と共によりよい宇宙開発につなげていきたいと願っております。

発表資料

ワークショップ１日目

平成19年10月29日（月）

R&D Activities for Fundamental Space Technologies in IAT

October 29, 2007

Akio Yamamoto
Associate Executive Director
Institute of Aerospace Technology (IAT)

Institute of Aerospace Technology

JAXA

Contents

1. Overview of the role of IAT
2. Structure and basic concepts of IAT
3. Project support (overview)
4. Research and Development activities (overview)

1. Overview of IAT

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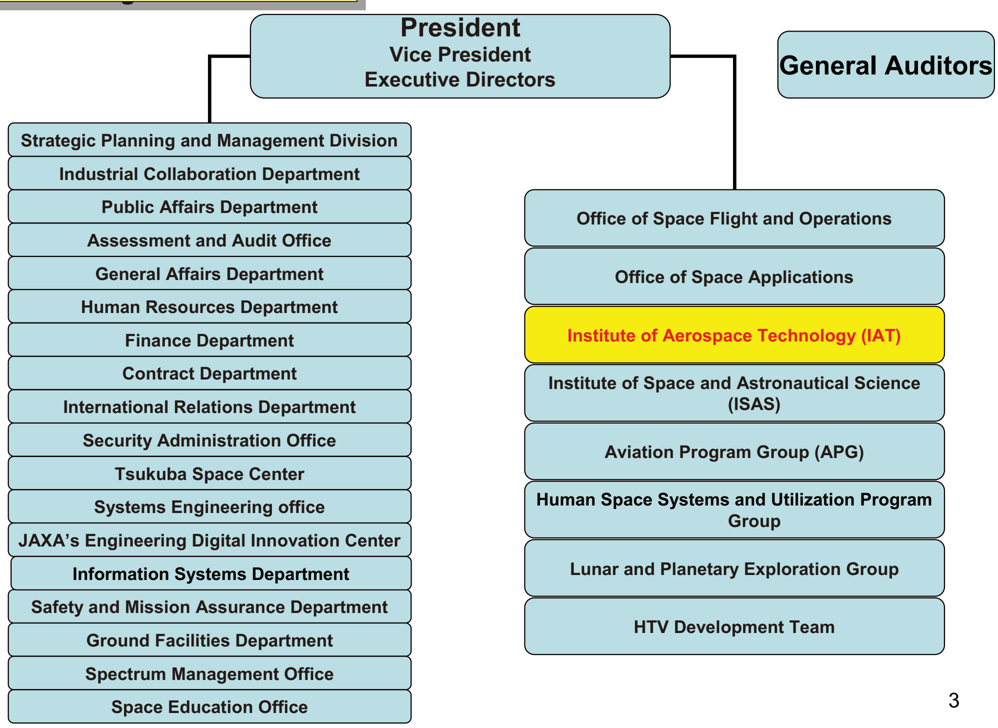
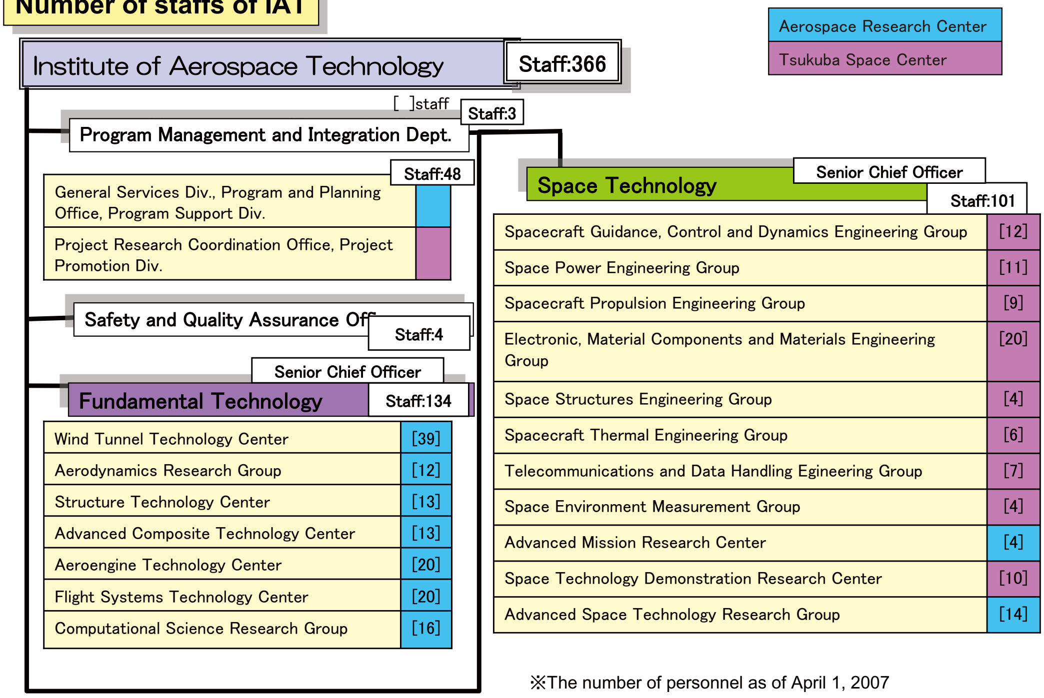
Organization



3

Number of staffs of IAT



※The number of personnel as of April 1, 2007

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Roles of IAT

➢Respond to urgent issues faced by the Japanese space community support project offices in developing common fundamental technologies to eliminate potential failures for on-going projects, and improve the reliability of future projects.

➢Support project offices in improving the reliability of satellites and solve project-related technical issues.

5

R&D for Next Projects - Components & Parts -

- Continue enhancing the fundamental component technologies to prevent potential spacecraft mission failure resulting from the increase of imported space equipment and components and decrease of domestic high-reliability components.

- Enhance R&D to sustain and grow domestic technologies for design, fabrication and quality assurance of the following critical units and components to assure independence of Japan's space development.

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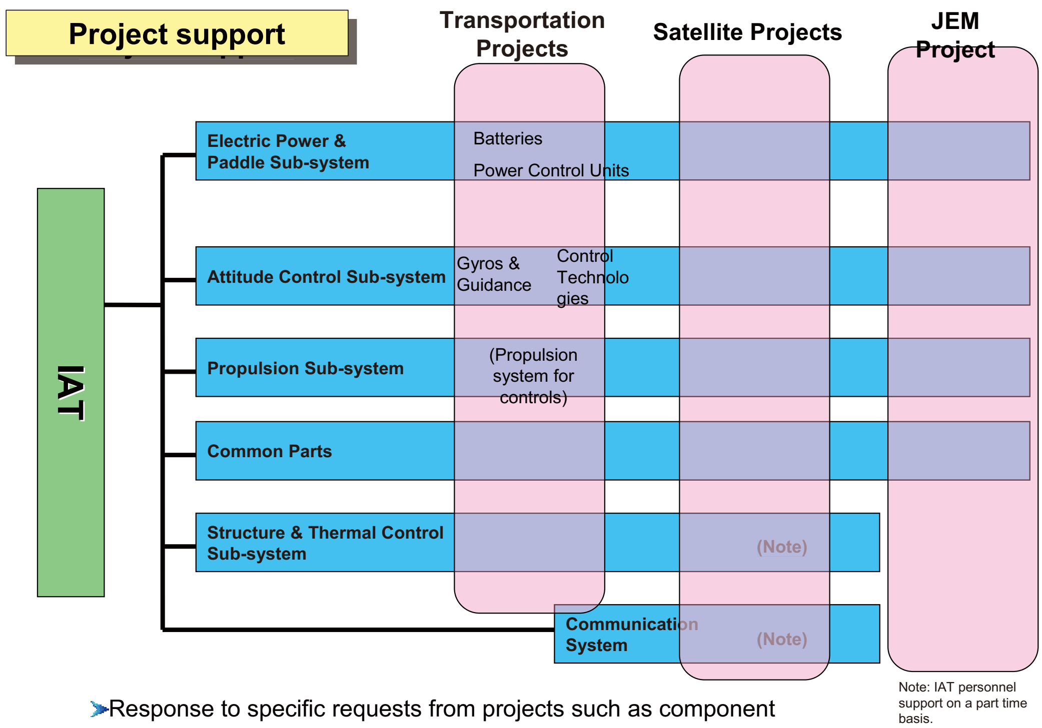

- Response to specific requests from projects such as component development and simulations.

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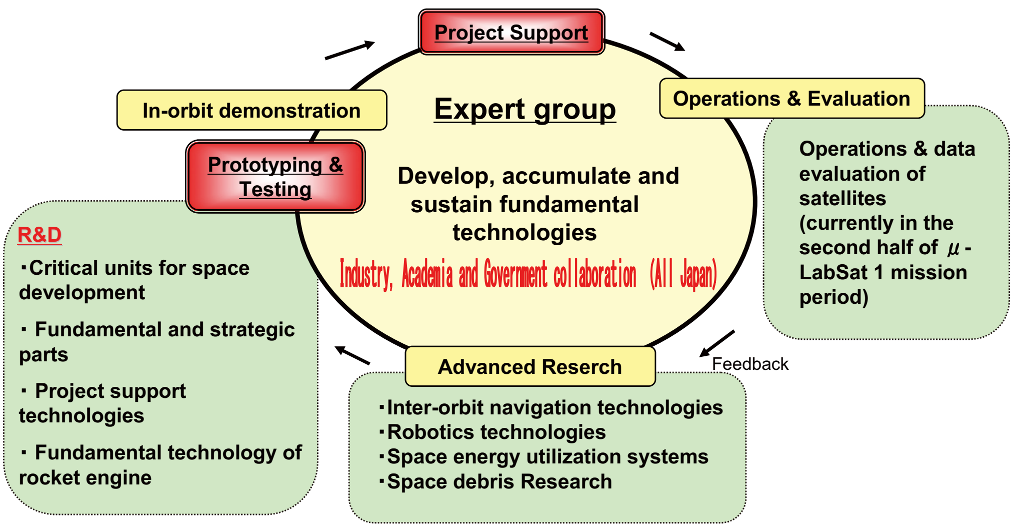
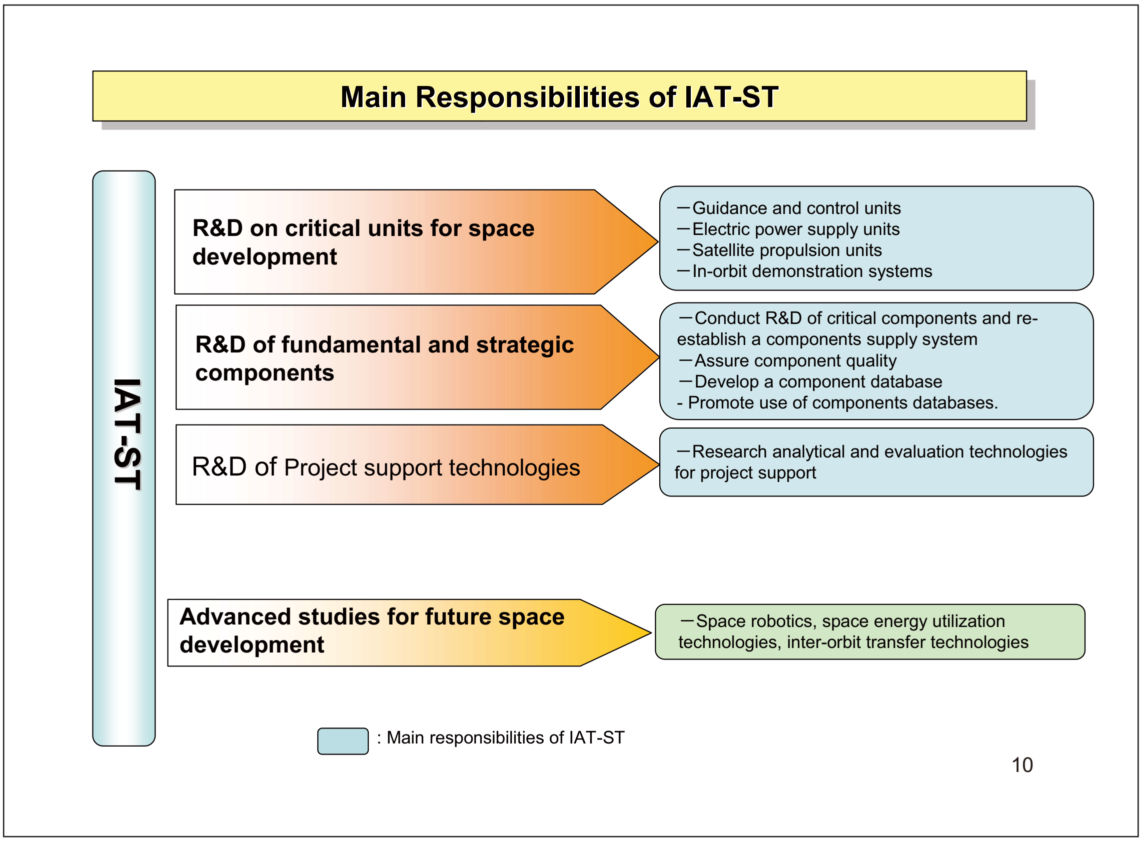
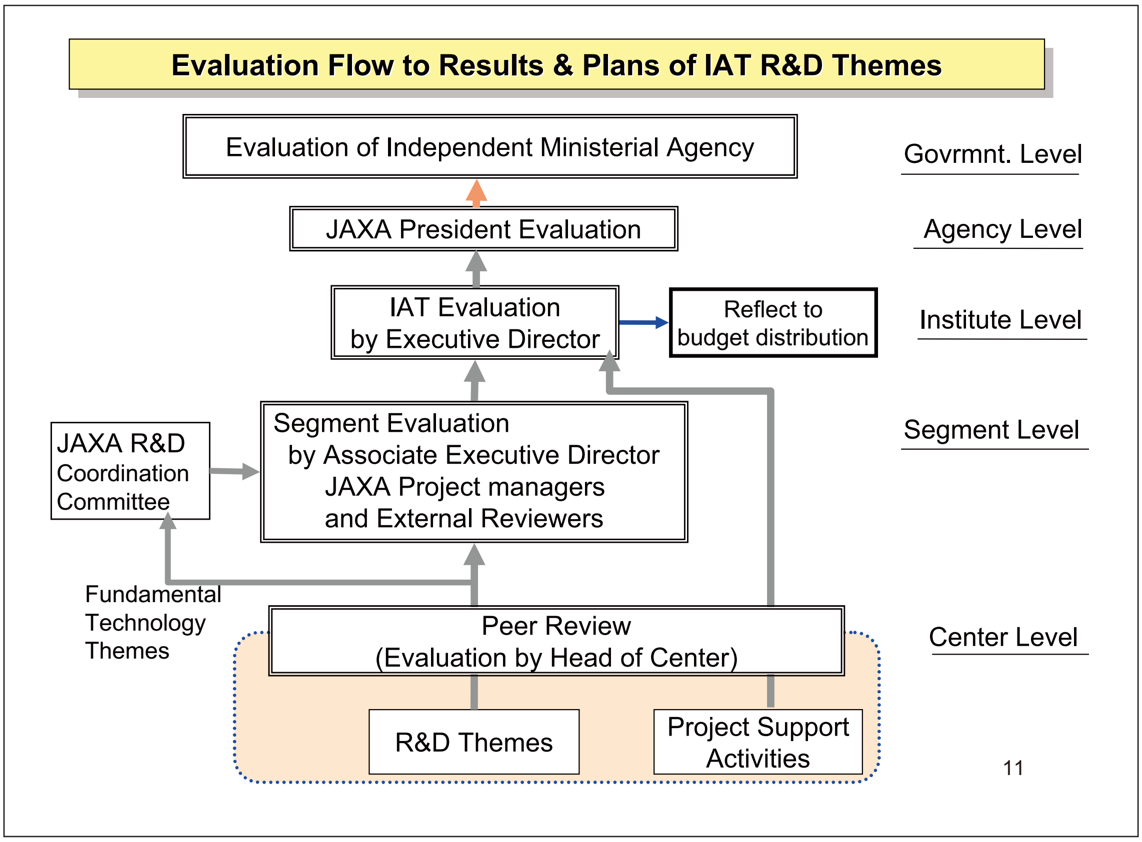
2. Basic concepts and strategy of IAT

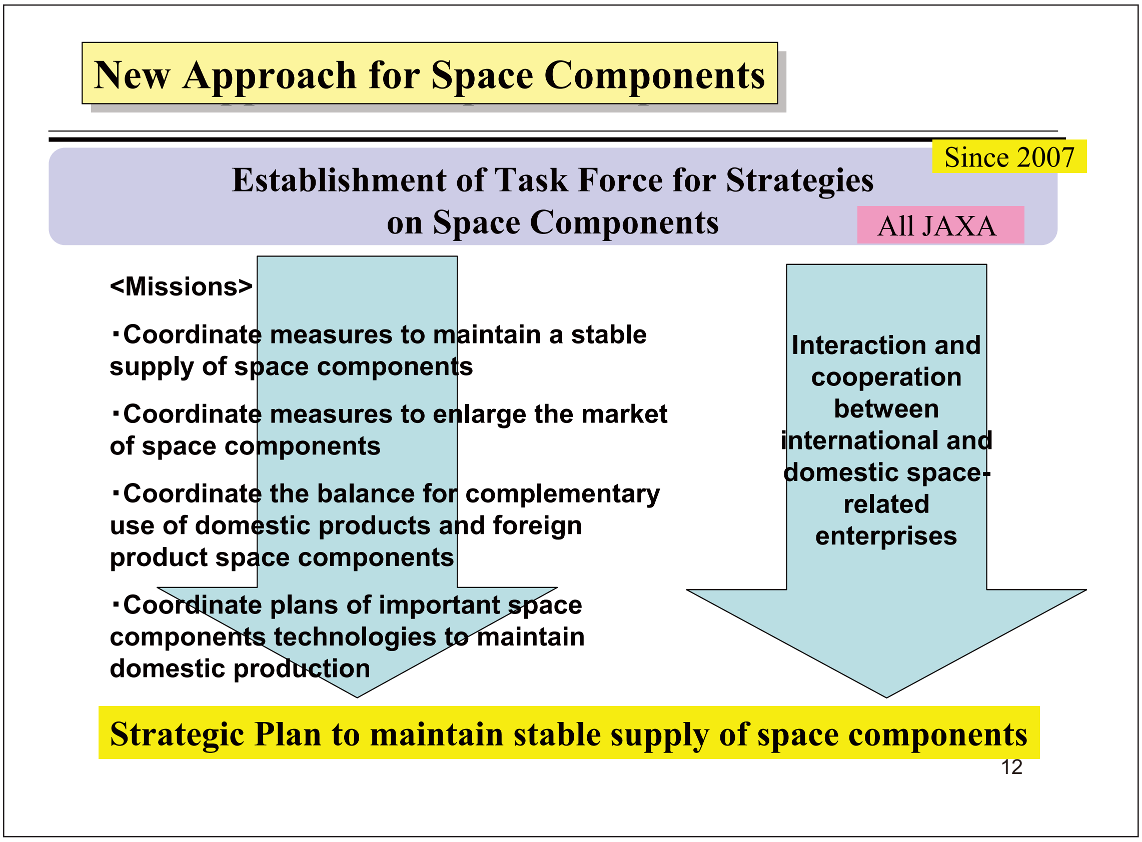
R&D Activities by IAT-ST※

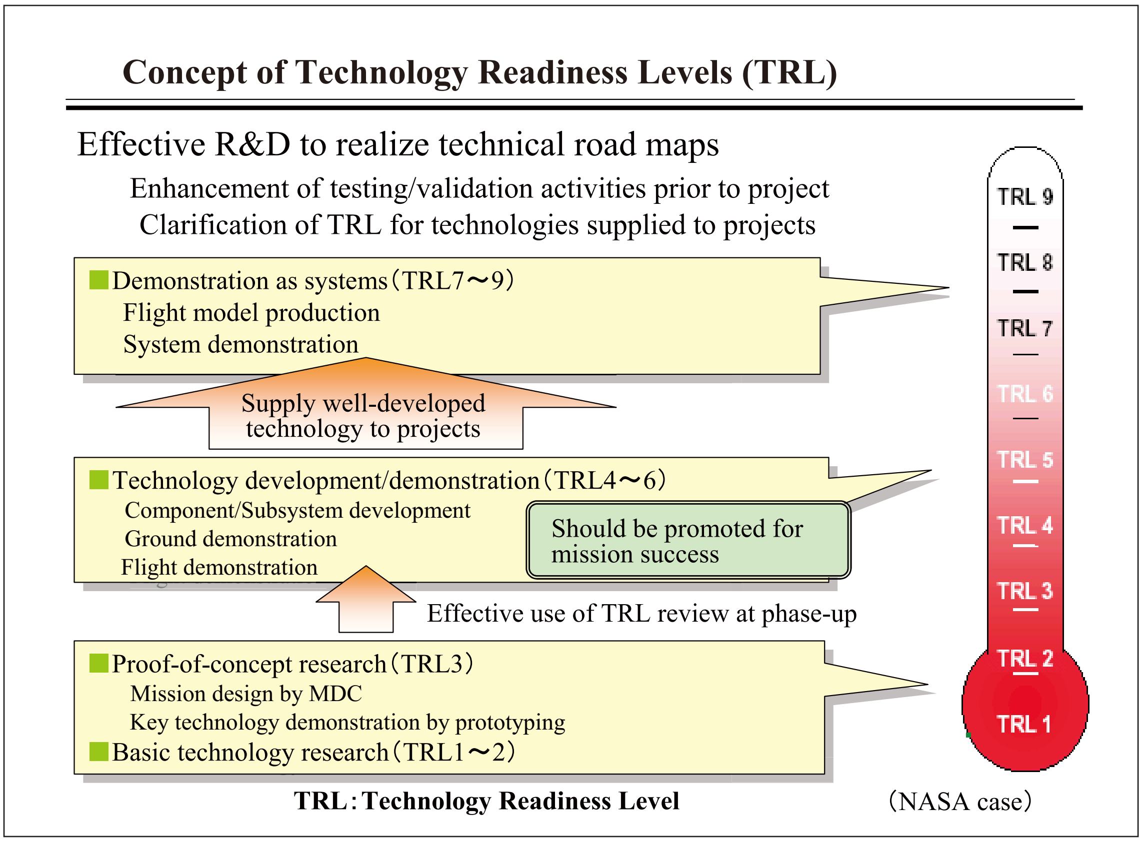


※ ST: Space Technology


Main Responsibilities of IAT-ST
IAT-ST
R&D on critical units for space development
—Guidance and control units
—Electric power supply units
—Satellite propulsion units
—In-orbit demonstration systems
R&D of fundamental and strategic components
—Conduct R&D of critical components and re-establish a components supply system
—Assure component quality
—Develop a component database
- Promote use of components databases.
R&D of Project support technologies
—Research analytical and evaluation technologies for project support
Advanced studies for future space development
—Space robotics, space energy utilization technologies, inter-orbit transfer technologies
: Main responsibilities of IAT-ST
10

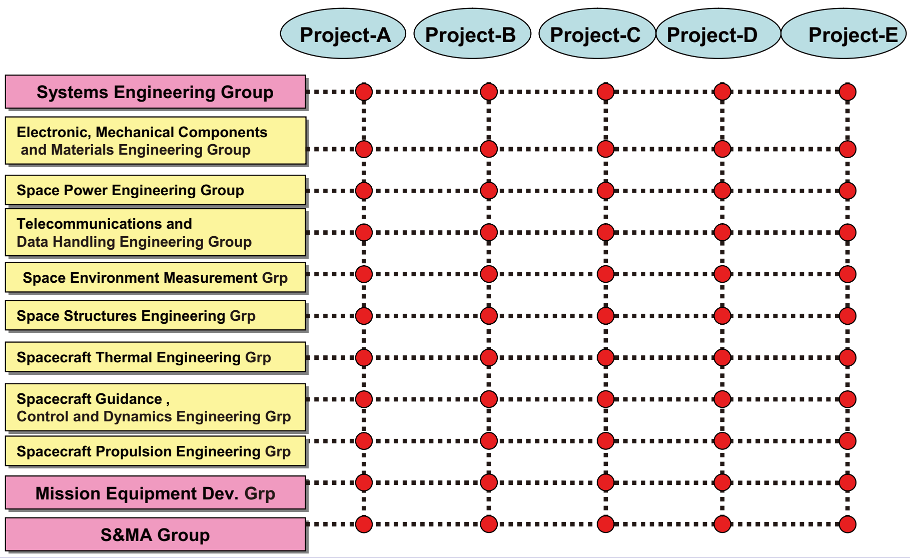

Evaluation Flow to Results & Plans of IAT R&D Themes
Evaluation of Independent Ministerial Agency
Govrmnt. Level
JAXA President Evaluation
Agency Level
IAT Evaluation by Executive Director
Reflect to budget distribution
Institute Level
JAXA R&D Coordination Committee
Segment Evaluation by Associate Executive Director JAXA Project managers and External Reviewers
Segment Level
Fundamental Technology Themes
Peer Review (Evaluation by Head of Center)
Center Level
R&D Themes
Project Support Activities
11


New Approach for Space Components
Establishment of Task Force for Strategies on Space Components
Since 2007
All JAXA
<Missions>
・Coordinate measures to maintain a stable supply of space components
・Coordinate measures to enlarge the market of space components
・Coordinate the balance for complementary use of domestic products and foreign product space components
・Coordinate plans of important space components technologies to maintain domestic production
Interaction and cooperation between international and domestic space-related enterprises
Strategic Plan to maintain stable supply of space components
12


Concept of Technology Readiness Levels (TRL)
Effective R&D to realize technical road maps
Enhancement of testing/validation activities prior to project
Clarification of TRL for technologies supplied to projects
Demonstration as systems（TRL7～9）
Flight model production
System demonstration
Supply well-developed technology to projects
Technology development/demonstration（TRL4～6）
Component/Subsystem development
Ground demonstration
Flight demonstration
Should be promoted for mission success
Effective use of TRL review at phase-up
Proof-of-concept research（TRL3）
Mission design by MDC
Key technology demonstration by prototyping
Basic technology research（TRL1～2）
TRL 9
TRL 8
TRL 7
TRL 6
TRL 5
TRL 4
TRL 3
TRL 2
TRL 1
TRL：Technology Readiness Level
（NASA case）

3. Project Support (overview)

Contribution of DE groups in the project
(The Matrix organization)



Establish DE groups and participate in projects as the expert of each subsystem
→Contribution to the Mission Success of satellite projects

Solutions by IAT for key technical issues

H-IIA Launch Vehicle H-IIA launch vehicle is the Japan's primary large rocket equipped with high performance engines that use liquid oxygen and hydrogen as propellants.

===== ======================【Support by IAT】============================

- Flight analysis
- Analysis and evaluation of post-flight vibration data
- Analysis and evaluation on components of guidance, control and dynamics
- Support analysis for embarking small satellites

H-IIB Launch Vehicle The H-IIB launch vehicle is a rocket under development equipped with 2 LE-7A high performance engines by liquid oxygen and hydrogen. The rockets will add 1m to the vehicle diameter and length and it will become possible to load 1.7 times the propellants of H-IIA.

===== ======================【Support by IAT】============================

- Support design of avionics system
- Analysis and evaluation of lithium-ion battery

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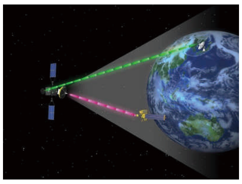
Summary of Project Supports (sheet 1 of 4)



DRTS DRTS is a data relay satellite, it is a GEO communication satellite used to relay communications between medium to low altitude (300 - 1,000 km) spacecraft.

=====================【 Support by IAT 】==========================
Telemetry evaluation (e.g., thermal, electric power system such as 50 Ah Ni-H2 batteries, Earth sensor and attitude control system such as wheels）

ALOS ALOS is one of the world's largest earth observation satellites, with higher performance than JERS-1 or ADEOS.

=====================【Support by IAT】==========================
Experts from each discipline of the IAT participated in the ALOS comprehensive review team. Charging and discharging tests were used as part of the ADEOS-II failure investigation along with all necessary tests to prevent similar failure. Those experts developed versions IV & V of the flight software conducted radiation tests for the heavy particle monitoring sensor and light particle monitoring sensor to calibrate these sensors. They tested the star sensor and supported it in the off-line attitude determination system. They measured space radiation environment and supply its data to avoid heavy damage.

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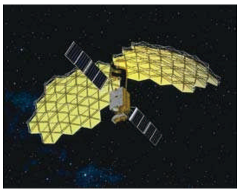
Summary of Project Supports (sheet 2 of 4)



ETS-Ⅷ ETS-VIII, an engineering test satellite, is designed to meet communication demands for cellular phones and mobile equipment. Two deployable antenna and two solar

=====================【Support by IAT】========================
Experts of each discipline of the IAT formed the ETS-VIII comprehensive review team and evaluated results of ion engine operation tests. They calibrated sensors (e.g. charge sensor, used a loop heat pipe to generate a mathematical thermal model of the deployable radiator, evaluated flexible structures, developed a 100 Ah Ni-H2 battery, supported extensive radiator operation, and made solar flare avoidance maneuvers.

WINDS The R&D of WINDS, a joint project between JAXA and National Institute of Information and Communications Technology to develop the most advanced information network, is being implemented under the e-Japan Priority Policy Program, established by the IT Strategy Office.

=====================【Support by IAT】========================
The IAT performed thermal and structure analyses of satellite system, communication, and other mission equipment. They supported solar cell evaluation and electric power system design, assessed possible malfunctions of the tuned dry gyro, and supported the component program.

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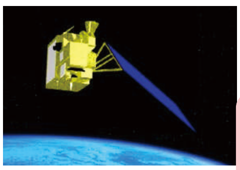
Summary of Project Supports (sheet 3 of 4)

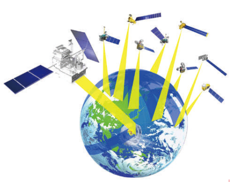
SELENE The SELenological and Engineering Explorer (SELENE) is Japan's first large lunar explorer. This is the largest lunar exploration project since the U.S. Apollo project. It has drawn attention from around the world. (ISAS project)

======================【Support by IAT】=========================
For this project, IAT supported analysis, planning, and design of the landing, navigation, guidance and control systems, communication and data handling system, and procurement of 35 AhNi-Cd batteries and 13 AhNi-MH batteries. Furthermore, IAT consulted on space-use parts applications, supported the propulsion subsystem design and subsystem ignition tests, and supported analyses of materials and mechanical parts.



GOSAT This is a joint project between JAXA and the Ministry of the Environment. GOSAT is a Japanese contribution to the Kyoto Protocol, created at the third session of the Conference of the Parties to the U.N. Framework Convention on Climate Change (COP3) and to Global Climate Observation System. GOSAT will measure the distribution of CO2, which worsens the greenhouse effect, from space.

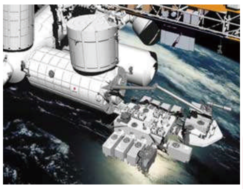
======================【Support by IAT】=========================
IAT supported R&D of onboard equipment: space environment measurement equipment and newly developed components and parts (e.g., high-speed wheel, 200 MIPS 64 bit MPU and DC/DC converter); and thermal evaluation of high-efficiency solar cells.



GPM／DPR GPM and DPR respectively stand for Global Precipitation Measurement and Dual-frequency Precipitation Radar. The GPM mission includes the Core Spacecraft and some 8 constellation satellites. Core Spacecraft is equipped with DPR, which measures precipitation using two radio frequencies, and GPM Microwave Imager.

======================【Support by IAT】=========================
For this project, IAT supported the parts program, thermal design of the radiator, and material technology, along with analysis of heat balance and structure. It also supported analysis of materials that are able to withstand a space environment.

Summary of Project Supports (sheet 4 of 4)

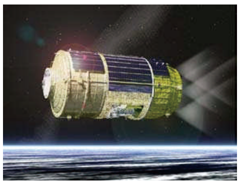


JEM Pressurized Module/Exposed Module/Manipulator, Space Experiment Equipment

JEM "Kibo" is the Japanese contribution to the International Space Station. JEM includes two experiment elements; the pressurized laboratory and the exposed platform. JEM also includes pressurized stowage as part of a pressurized laboratory and the exposed pallet as part of the exposed platform, the robotic manipulator for experiments and other tasks, and a communication system with satellites.

=====================【Support by IAT】========================

・Offgassing test, flammability test and odor test. Noise measurement and evaluation.
・Supported MATOF platform development and outgas measurement from organic materials (e.g. FRP).
・Evaluated the long-term accuracy of harmonic drive damper used for the small manipulator joint. Provided technical support of the Parallel Computer System (PCS), which is used as part of the backup computer for the manipulator controller. The PCS was mounted on MDS-1.
・Safety evaluation of batteries embedded in small, portable equipment.
・Analysis malfunction of electronic and mechanical components.

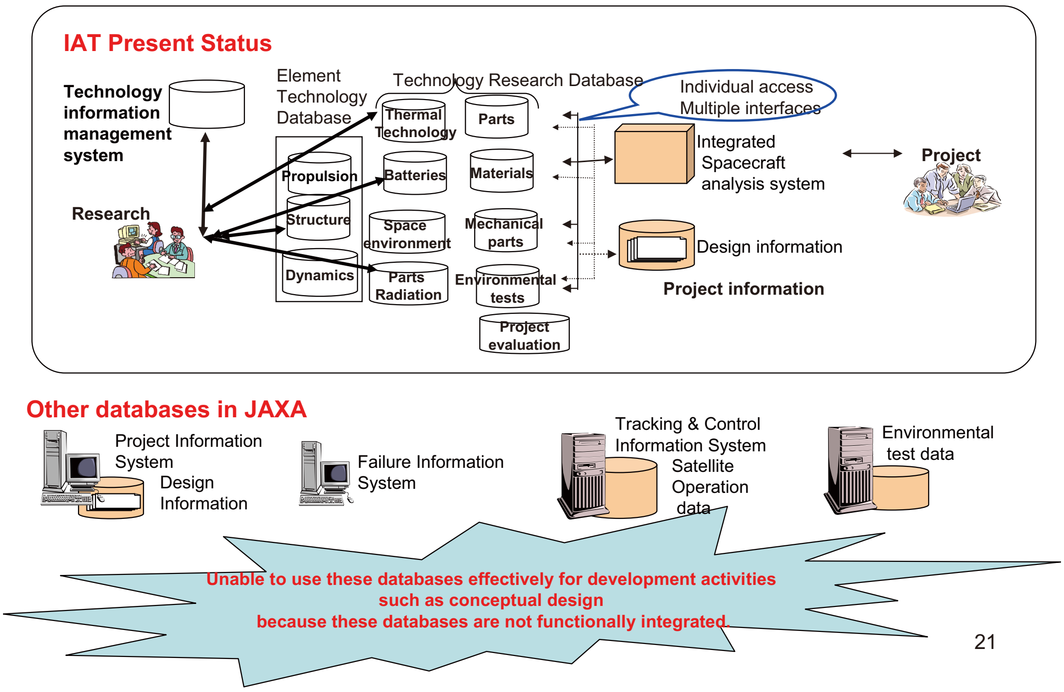


HTV H-II Transfer Vehicle (HTV) is a resupply vehicle for the ISS. The HTV is an unmanned vehicle designed to be attached on top of the augmented H-IIA launch vehicle. It delivers a maximum of 4 tons of food, clothes, and various experimental equipment to the ISS and brings used experimental equipment and clothes back to the atmosphere. Each HTV is burned up during re-entry.

=====================【Support by IAT】========================

For this project, IAT performed R&D of the rendezvous sensor, evaluated the lubrication segments for friction characteristics and lifetime, evaluated imported mechanical components (low-impact separation mechanism), supported rendezvous docking testing, supported batteries and electric power system, supported the operational phase using the distributed simulator, and supported analysis of each segment.

Development of Fundamental Technology Database



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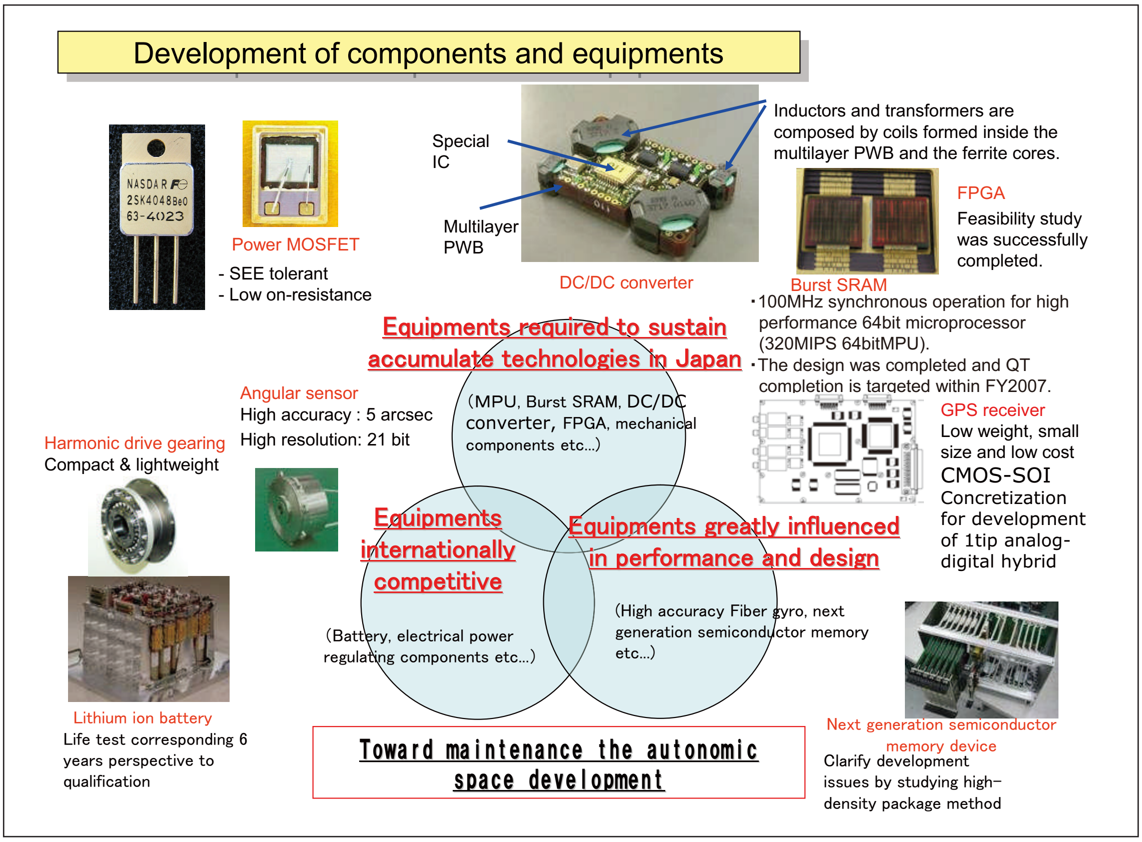
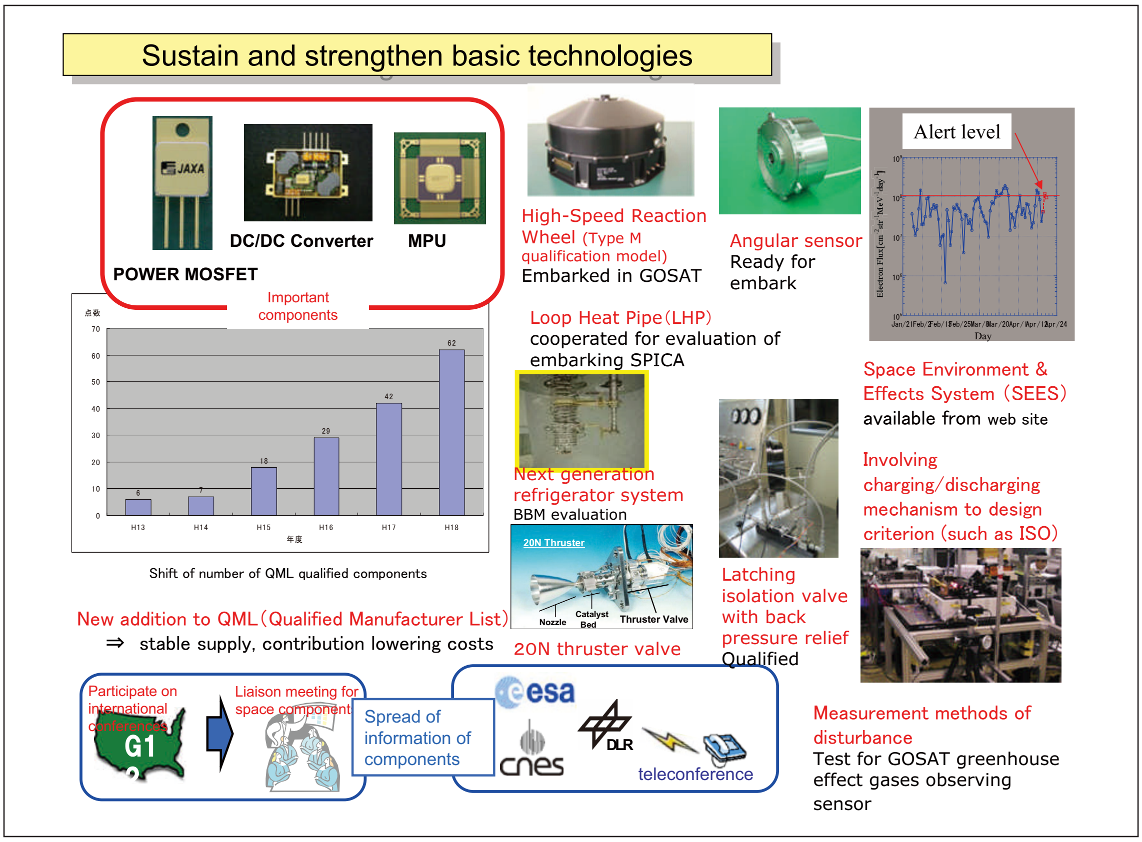
Enhance existing technical databases

Database	Summary	Status
Common Parts Database	Database integrated to provide information on JAXA (formerly NASDA) qualified parts.	Open to Public/Restricted
Parts Test Data Analysis System	Database of solar cells including data such as radiation test data, flight heritage and failures. This database also provides search and retrieval capabilities of test and analytical results.	Open to Public/Restricted
Guidance Control Information System	Database of dynamics, navigation and guidance, results on robotics research such as materials, numerical data and evaluation results.	In Group Only
Mechanisms & Parts Database	Database of space-use mechanical components and systems including research results and design standards related to mechanical components and systems.	In Group Only
Structure Information Database	Database of results of structural system studies such as materials, numerical data, and evaluation results.	Under construction
Space Environment Measurement Information System	This database has a radiation environment simulation function including satellite anomaly warning notification function and satellite environmental information supply function. This database also has a function to utilize stored data.	Open to Public/Restricted
Micro Electro Mechanical Systems	This database maps the technology of micro electro mechanical systems (MEMS) of Japan.	In house Only
Battery Life Database	Added capability to register past data and compare in-orbit operational data and ground-based test data for batteries used for satellites that are to be operational in the future. Converted "Collection of Battery Cleaning Test Base Data" into an electronic file, which is distributed to related parties and added to the database.	In house Only
Material Database	Database of outgassing test, safety demonstration test, material evaluation test and space demonstration data.	Open to Public/Restricted
Thermal Design Analysis Information System	Database of thermal design technology such as design materials, mathematical thermal models, chamber test data, in-orbit data, and other thermal-related data.	In house Only

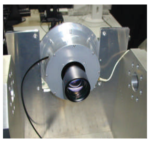
4. Research & Development activities (overview)


Development of components and equipments
Power MOSFET
- SEE tolerant
- Low on-resistance
Special IC
Multilayer PWB
DC/DC converter
Inductors and transformers are composed by coils formed inside the multilayer PWB and the ferrite cores.
FPGA
Feasibility study was successfully completed.
Burst SRAM
・100MHz synchronous operation for high performance 64bit microprocessor (320MIPS 64bitMPU).
・The design was completed and QT completion is targeted within FY2007.
Equipments required to sustain accumulate technologies in Japan
(MPU, Burst SRAM, DC/DC converter, FPGA, mechanical components etc...)
Angular sensor
High accuracy : 5 arcsec
High resolution: 21 bit
Harmonic drive gearing
Compact & lightweight
Equipments internationally competitive
(Battery, electrical power regulating components etc...)
Equipments greatly influenced in performance and design
(High accuracy Fiber gyro, next generation semiconductor memory etc...)
GPS receiver
Low weight, small size and low cost
CMOS-SOI
Concretization for development of 1tip analog-digital hybrid
Lithium ion battery
Life test corresponding 6 years perspective to qualification
Toward maintenance the autonomic space development
Next generation semiconductor memory device
Clarify development issues by studying high-density package method


Sustain and strengthen basic technologies
POWER MOSFET
DC/DC Converter
MPU
Important components
Shift of number of QML qualified components
New addition to QML (Qualified Manufacturer List)
⇒ stable supply, contribution lowering costs
High-Speed Reaction Wheel (Type M qualification model)
Embarked in GOSAT
Angular sensor
Ready for embark
Alert level
Loop Heat Pipe (LHP)
cooperated for evaluation of embarking SPICA
Next generation refrigerator system
BBM evaluation
20N Thruster
Nozzle
Catalyst Bed
Thruster Valve
20N thruster valve
Latching isolation valve with back pressure relief
Qualified
Space Environment & Effects System (SEES)
available from web site
Involving charging/discharging mechanism to design criterion (such as ISO)
Participate on international conference
Liaison meeting for space component
Spread of information of components
esa
cnes
DLR
teleconference
Measurement methods of disturbance
Test for GOSAT greenhouse effect gases observing sensor

Guidance and Control Units

➢ **Advance the accuracy, weight, and reliability of attitude-control technology, the brain of a spacecraft, and strengthen its international competitiveness.**


Star sensor

■ **Star Sensor(SST):**

A next-generation star sensor that can determine the attitude autonomously, is being developed. Utilizing a high-performance MPU, high accuracy and small size are achieved. A prototype has been built and evaluated.


High Speed Reaction Wheel(HSRW)

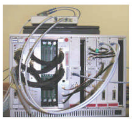
■ **Wheel:**

We are developing two new Reaction Wheels; a High-Torque Reaction Wheel (HTRW) and High-Speed Reaction Wheel (HSRW). Actually, HTRW is for a future observation mission and has characteristics of high torque and low disturbances. The HSRW is for general missions and has characteristics of small/light and low disturbances. HSRW will be launched on GOSAT in 2008.


Fiber optic gyro (FOG)

■ **Fiber Optic Gyro(FOG):**

Aiming for the application to the future spacecraft attitude control system, a high-performance Fiber Optic Gyro, which employs a high-power erbium-doped fiber light source and a long fiber coil (3 km), is now under development. A prototype has been built and evaluated.

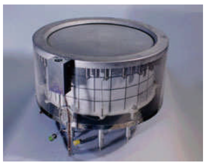

Next generation GPS receiver

■ **Next Generation GPS Receiver:**

The new space-borne GPS receiver was investigated, which can track 24 satellite signals including the L2 new civil code. Because of dual frequency utilization, the ionospheric delay error is reduced dramatically. A functional model has been built and evaluated.

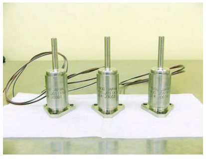
Satellite Propulsion Units

➢ **For supplying reliable satellite propulsion subsystem**


150mN Class Ion Engine

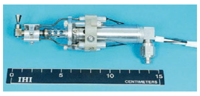
■ **150-mN class Ion engine and electric propulsion mission concept.**

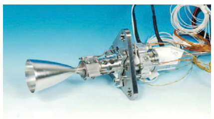
⇒–Lengthening the grid lifetime and improving the durable grid design against launch vibration. Conceptual mission study for using advantages of large thrust and high Isp.


Thruster Valve

■ **The 20N class thruster valve**

⇒Development the reliable 20N class thruster valve. Reliable technology applied Design Review Based Failure Modes (DRBFM)




Monopropellant Thruster

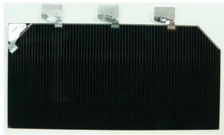
■ **Continuous improvement activity of propulsion components and systems**

⇒Thrusters, engines, valves, tanks, material, propellant, ...etc.

Electric Power System

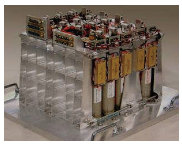
➢ **Reducing the power system mass and cost by improving their lifetime, performance, and reliability to increase spacecraft competitiveness.**

■ **High-Efficiency Solar Cells**:
Triple-junction (3J) solar cells were developed; they demonstrated greater than 28% conversion efficiency. The 3J cells have been qualified and utilized for WINDS, GOSAT, and other GEO/LEO satellites. A thin-film flexible dual-junction solar cell is now under development to reduce the cell weight to 1/10 or less.



Triple-junction Solar Cell

■ **Lithium Ion Batteries**:
The life of lithium ion batteries has been investigated. Long cycle-life tests under LEO and GEO operation conditions were achieved at over 1,500 and 35,000 cycles, which are respectively equivalent to more than 6 years and 15 years. Lithium ion batteries have an advantage of 50% weight reduction compared to existing alkaline batteries and will be used for future spacecraft.

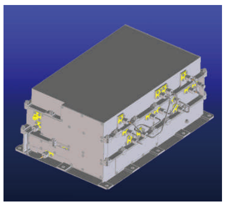


100Ah-10 series Lithium-Ion Battery Assembly

Telecommunications and Data Handling

➢**Telemetry, tracking and command (TT&C) is a key system for spacecraft operations. High performance and multifunctional transponders are required. Data recorders are indispensable for the massive data processing required for advanced space missions with higher precision.**

■**Multi-mode Integrated Transponder (MTP)**
A New S-band transponder for TT&C operation is under development. The MTP integrates four radio transmission modes: USB, SSA, QPSK, and CDMA. The MTP capability will be demonstrated on the SDS-1.



Multi-mode Integrated Transponder (TBD)

■**Solid State Recorder (SSR)**
Developing a high-speed, high-capacity and low-power consumption solid state recorder (SSR) for space use aiming for installation on Earth observation (EO)sattelites. 200 GByte capacity, total 2.5 Gbps (four channels) data transmission speed, low weight (25 kg) and low power consumption (120 W) developed EM in 2005. A 512 Mbit synchronous dynamic random access memory (SDRAM) with an on-board multi-bit error detection and correction (EDAC) mechanism, as well as a Compact-PCI bus for fast data exchange, all improve the efficiency of data collection and storage. Currently modifying to fit Double Data Rate 2 SDRAM (DDR2) and studying a non-volatile data recorder using flash memory.

3rd generation Solid state recorder using SDRAM

Space Environment Measuring Instruments 1/2

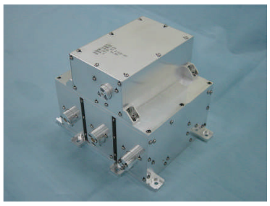
➢These instruments measure space radiation environments that might induce satellite failure and contribute to improving space environment models that are used to optimize satellite design and operation planning, which enhances the fundamental technologies.

- **Conduct R&D of instruments such as the small and lightweight "light particle telescope*".**
  *Currently, flight-models of this instrument are under evaluation. This instrument will be used for GOSAT, Jason-2, and QZS.

- **Collected data are used to develop space environment models, which are used for spacecraft design.**

- **Furthermore, space environment data are made available in various ways such as for warning system of energetic solar particle event.**

French Satellite
Jason-2 (CNES)



Light Particle Telescope

※This is an instrument to count electrons, protons and α-particles, and measure the energy distribution accurately.

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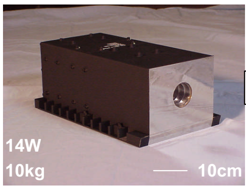
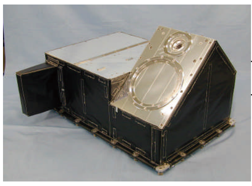
Space Environments Measuring Instruments 2/2

Radiation (electrons, protons and α particles)

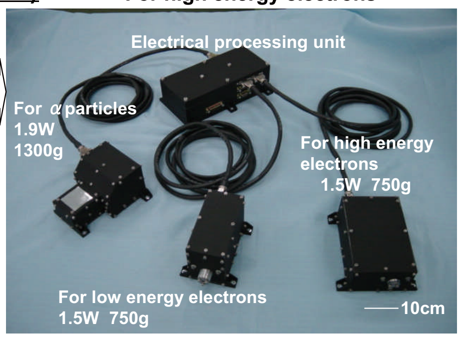


For Tsubasa, Kodama, Kibou
Electronics（0.4～9MeV）
Protons （0.9～210MeV）
α particles（6.5～140MeV）



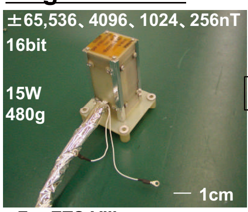
For Daiti
Electrons （0.3～10MeV）
Protons （1.5～250MeV）
α particles（6～250MeV）

For high energy electrons

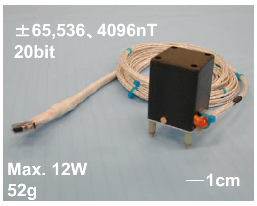


New development for GOSAT, Jason-2 & QZS
Electrons （0.03～20MeV）
Protons （0.4～500MeV）
α particles（3～2000MeV）

Magnetometer



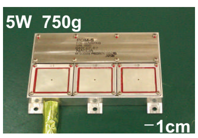
For ETS-VIII



New development

Contribute to satellite design and operation planning in JAXA

Potential monitor



For ETS-VIII

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Basic Approach for In-Orbit Demonstration

Continue providing timely space demonstration opportunities

- **Use space equipment developed by the R&D group or industry to space demonstration missions, projects and markets in a timely manner.**
- **Currently, opportunities of timely and cost-effective space demonstration are less.**

Benefits of In-Orbit Demonstration

①In-orbit demonstration is indispensable before actual use in space.
(e.g. flight-proven equipment must be used for commercial satellites)

②Verify technologies that cannot be verified on the ground.
(e.g. LDREX)

③Enhance fundamental technologies through comparison of ground-based tests and in-orbit demonstrations. (e.g. MDS-1/μ-LabSat)

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Achievements of In-Orbit Demonstration

MDS-1 Tsubasa

Use of results for next generation satellites

(1) New satellite development method:
—Short duration (3 years) and low cost development

(2) Use of COTS for space applications:
—Tested COTS in orbit using parts of the same lot used for ground-based tests. The result was used to establish ground-based evaluation technology and develop a guideline for test methods.

(3) Collection of new space radiation data and revision of the models:
—Revise radiation-hardening design standards.
—Influence the space environment design standards.

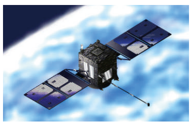
μ-LabSat-1

Use of results:

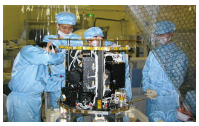
(1) Establish small satellite bus technologies:
—Acquire spin-stabilized satellite bus technology and three-axis attitude control technology.
—Acquire remote inspection technology.

(2) Increase space demonstration opportunities:
—Expect to serve as a platform for space. Perform demonstrations for evaluation of future space equipment. Expect to continue μ-LabSat project as a series.

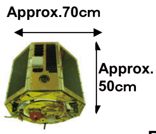
(3) Train young engineers:
—Contribute to training JAXA's young engineers to learn design, fabrication and testing technologies.



Commercial Semiconductor Device



In-house satellite development by JAXA's young engineers



Remote inspection technology experiment

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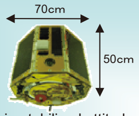
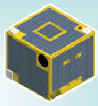
Orbital Demonstration

μ-LabSat



Left: No.1
Right: No.2



53kg, Spin-stabilized attitude control

50kg, 3-axis attitude control

Building small satellite bas technology:

- confirming small spinner bus technology and three-axis stabilized attitude control technology
- experiment of remote testing technology(NICT/the University of Tokyo/JAXA)
- accomplished operation for 3 years and 9 month (catalog life-span 6month). Contributed to development of young engineers.

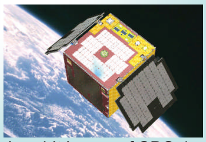
Small Demonstration Satellite (SDS) series

・Starting space demonstration program:

- Utilizing the technologies of μ-LabSat program, SDS program was established to demonstrate newly developed space technologies

100kgdegree demonstration satellite 1(SDS-1)

Vibration Test of structure model



In orbit image of SDS-1

Dissemination and utilization of technical outcomes of μ-LabSatNo.1

Technology transfer program of small satellite to the social community (Higashi-Osaka Satellite)

Assembling flight structure

SOHLA-1

Contribution to industrialization and local revitalization by small satellite development

Space demonstration : activities to strengthen fundamental space technologies

Flight experiment of newly developed equipment and components

- ➢Contribute to reliability improvement of each device and components
- ➢Acquire actual performance in space for encouraging the adoption in projects

NICT: National Institute of Information and Communications Technology

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Advanced Research

■**Objectives**

- ➢**Serve as the front runner to meet future needs.**
- ➢**Enhance and advance the technology base through challenges to further the progress of technologies.**

■**Approach**

- ➢**Programmatic approach based on a roadmap**
- ➢**Assess technical feasibility. Move forward steadily one step at a time.**

■**Themes**

- ➢**Expand space utilization and develop infrastructure to reach frontiers using manned missions.**
  - ■**Space robotics, rendezvous docking technology**
- ➢**Future space utilization missions**
  - ■**Space energy (space solar lights) utilization system**

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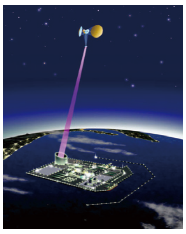
Major Advanced Research

Research on space energy (space solar lights) utilization systems



Space Solar Power Plant System (Concept)

➢This is a system to collect unlimited solar energy efficiently in a geostationary orbit and transfer the energy to the ground in the form of a microwave or laser.

Research to develop the system:
e.g. Plan in-orbit technology demonstration such as a technology demonstration plan near ISS*.

Research on element technologies:
e.g. Optimal design and element tests of high-power transmission technology, high-performance magnetron and microwave transmission system.

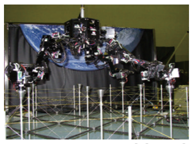
※ISS: International Space Station

Research on In-orbit Services

➢Reduce operational costs for future space systems through in-orbit assembly and re-supply using robotics and rendezvous/ docking technology.

Research to develop autonomous systems:
e.g. System concept studies on in-orbit work machines (e.g. re-fueling), assembly robots and inspection robots.

Research into element technologies:
e.g. Space robotics technology, rendezvous/docking technology, capture technology, image recognition/ automated and autonomous technology and remote manipulation technology.



Autonomous assembly robot

Satellite capture experiment

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Nissan's Quality Management

Oct 29th, 2007
Hiroshi KITAZAWA
Senior Manager
TCSX(Total Customer Satisfaction Function)
Field Quality Improvement Group
Nissan Motor Co., Ltd.

What is the quality in the vehicle

・**Mass production** （battle with variation）

・**Durable years**
（durability, Deterioration durability quality)

・**variously market environment**
- **natural environment**
（temperature, humidity, climate etc.）
- **Field environment**
（road condition, fuel properties etc.）

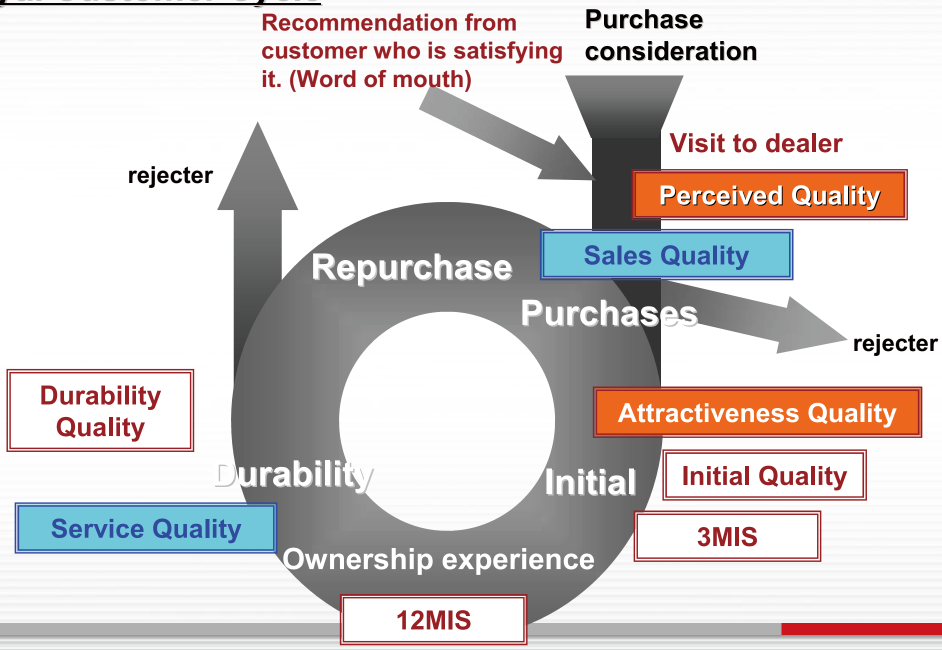
・**variously use condition**
- **User**（young、elder etc.）
- **How to use**（commute, shopping, leisure etc.）
- **Driving condition**
（traffic congestion, highway, climbing etc）

・**Perceived Quality**（luxury, comfort, relax etc.）

・**Recall system**

What is the quality in the vehicle

Royal Customer Cycle



Contents

- **Management situations surrounding quality**
- Quality improvement activities
- Ending remarks

Contents

Management situations surrounding quality

Quality improvement activities

Ending remarks

Quality Current Status

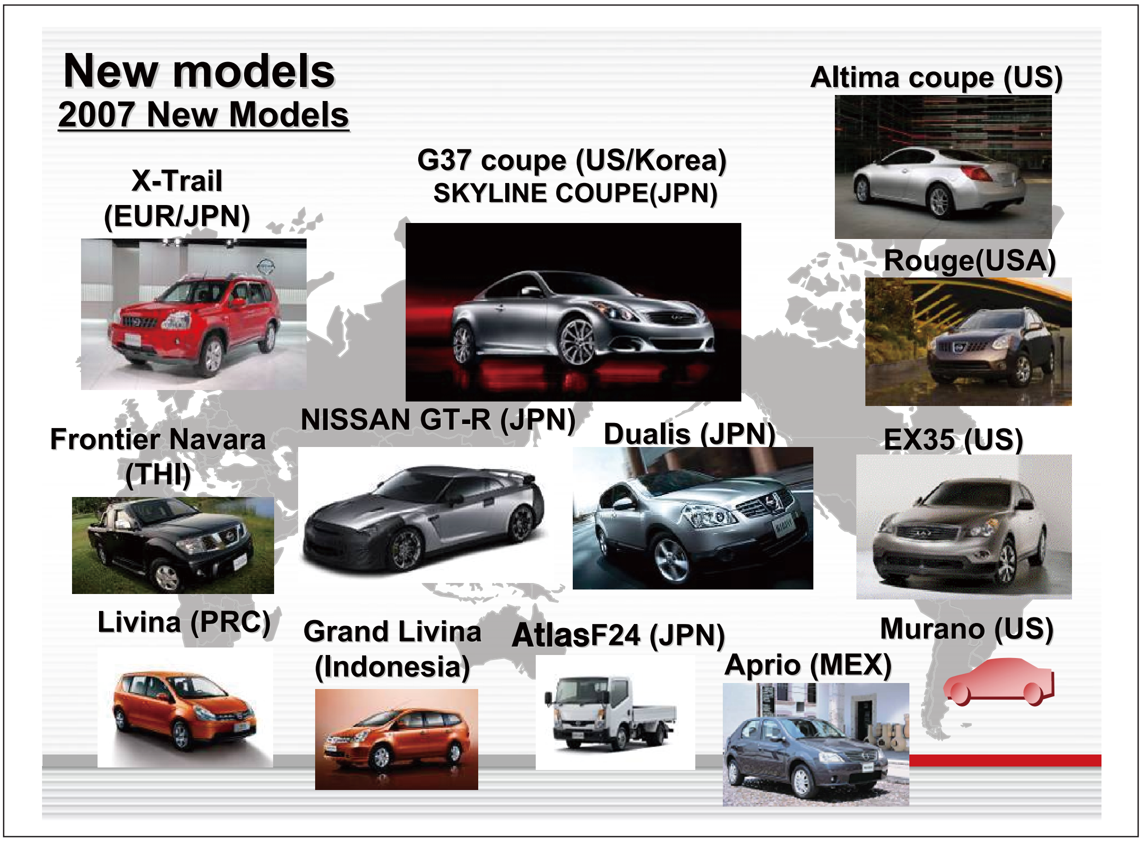
USA

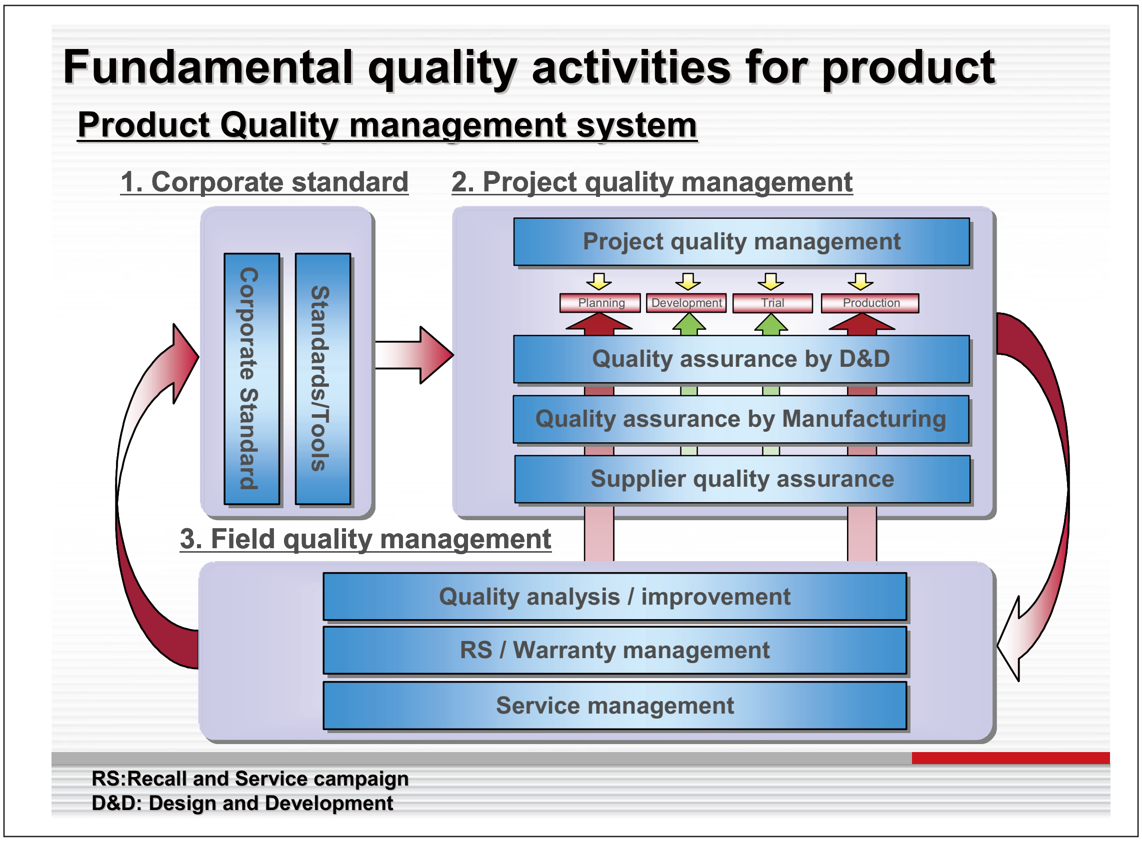
Consumer Reports "Top Picks"

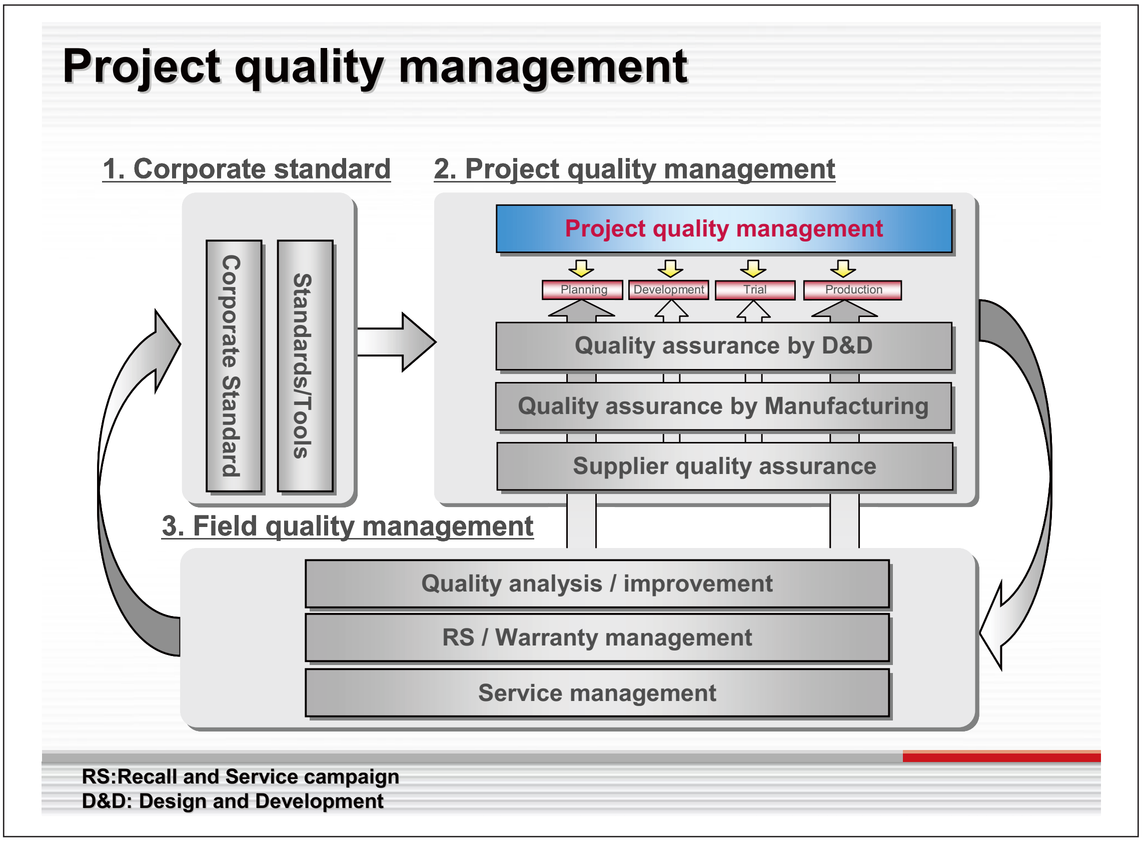
Issued April 2007

Upscale Sedan: Infiniti G35
Luxury Sedan: Infiniti M35

19 Segments


New models
2007 New Models
Altima coupe (US)
G37 coupe (US/Korea)
SKYLINE COUPE(JPN)
X-Trail
(EUR/JPN)
Rouge(USA)
Frontier Navara
(THI)
NISSAN GT-R (JPN)
Dualis (JPN)
EX35 (US)
Livina (PRC)
Grand Livina
(Indonesia)
AtlasF24 (JPN)
Aprio (MEX)
Murano (US)


Fundamental quality activities for product
Product Quality management system
1. Corporate standard
2. Project quality management
Corporate Standard
Standards/Tools
Project quality management
Planning
Development
Trial
Production
Quality assurance by D&D
Quality assurance by Manufacturing
Supplier quality assurance
3. Field quality management
Quality analysis / improvement
RS / Warranty management
Service management
RS:Recall and Service campaign
D&D: Design and Development


Project quality management
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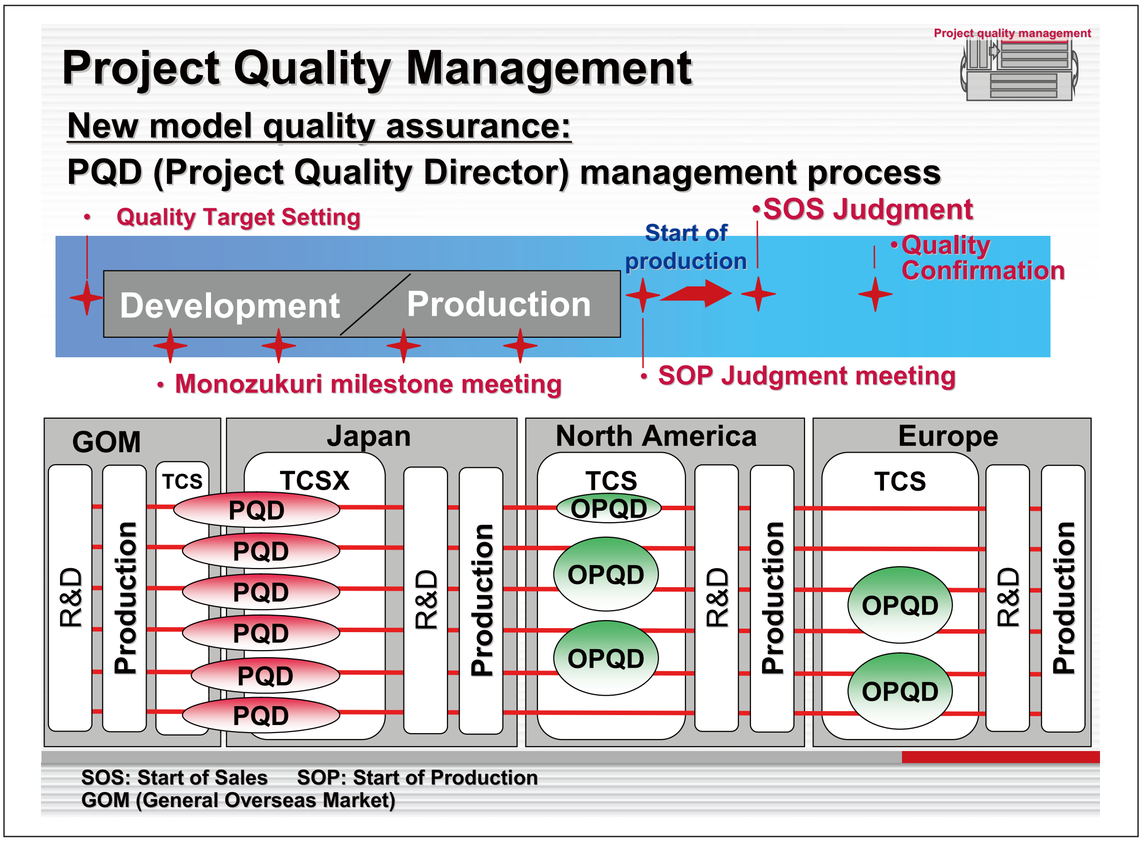

Project Quality Management
Project quality management
New model quality assurance:
PQD (Project Quality Director) management process
• Quality Target Setting
•SOS Judgment
Start of production
•Quality Confirmation
Development
Production
• Monozukuri milestone meeting
• SOP Judgment meeting
GOM
Japan
North America
Europe
TCS
TCSX
TCS
TCS
R&D
Production
PQD
PQD
PQD
PQD
PQD
PQD
OPQD
OPQD
OPQD
OPQD
OPQD
SOS: Start of Sales SOP: Start of Production
GOM (General Overseas Market)

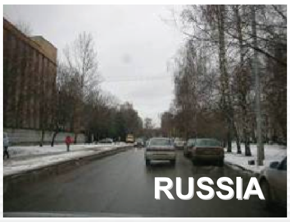
Project quality management

Project Quality Management

New Project Quality Assurance: PSQC (Pre-SOS Quality Clinic)

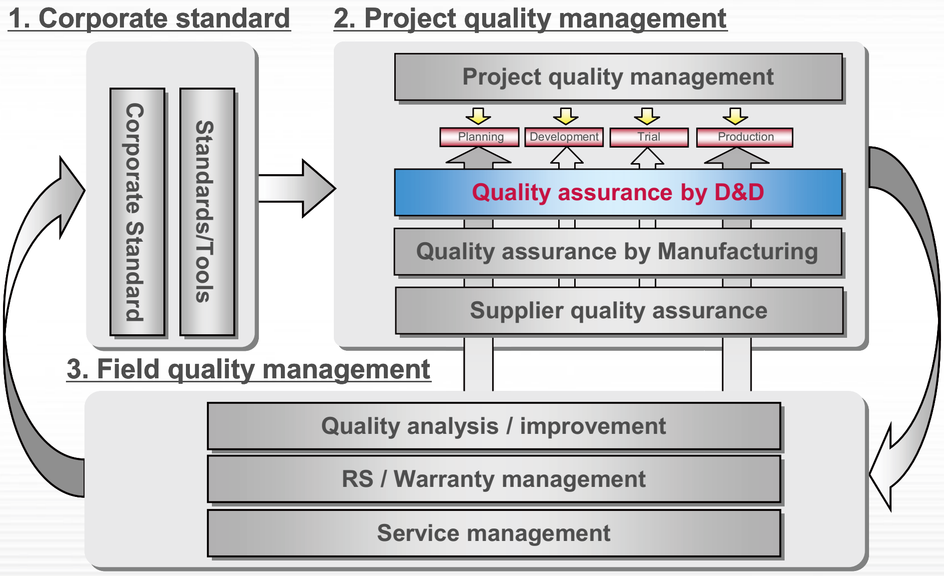
This is quality inspection system, which includes running tests conducted under the regional road and environmental conditions our customers will encounter.

In SKYLINE, ran about 430,000km total and carried out prior problem extraction and measures

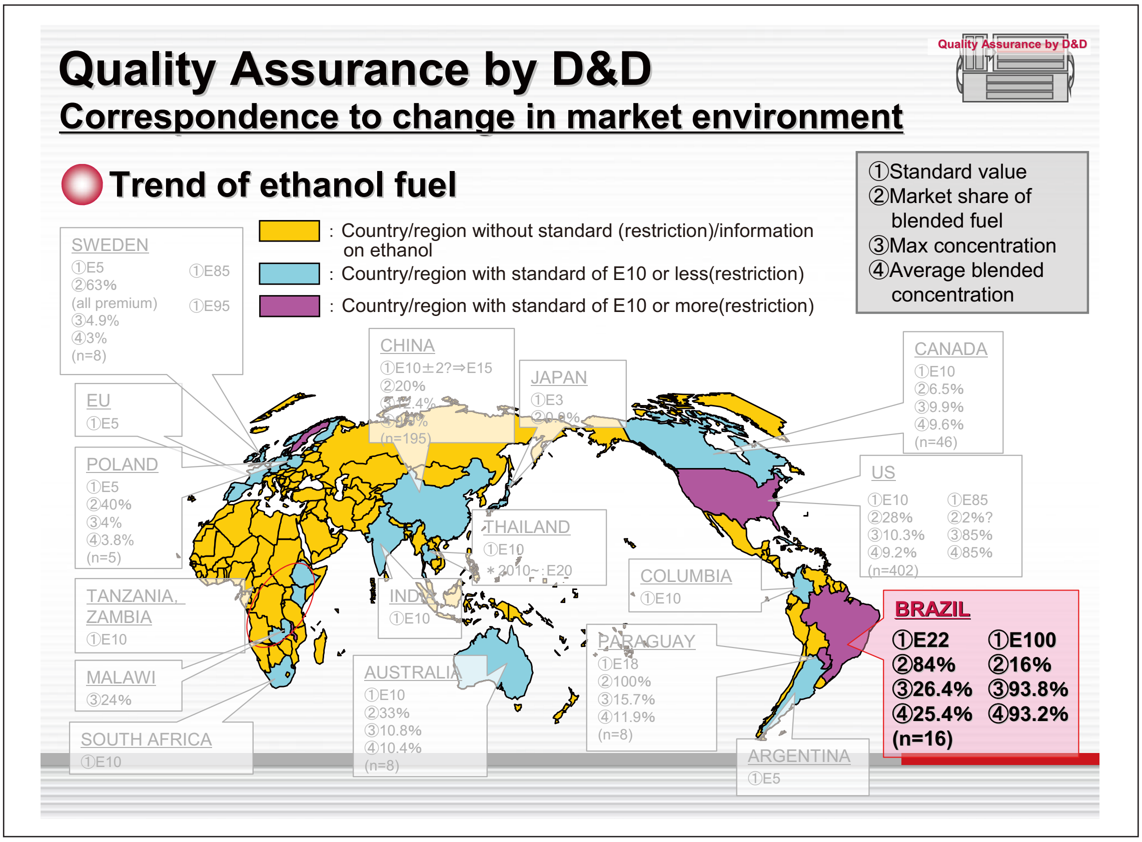


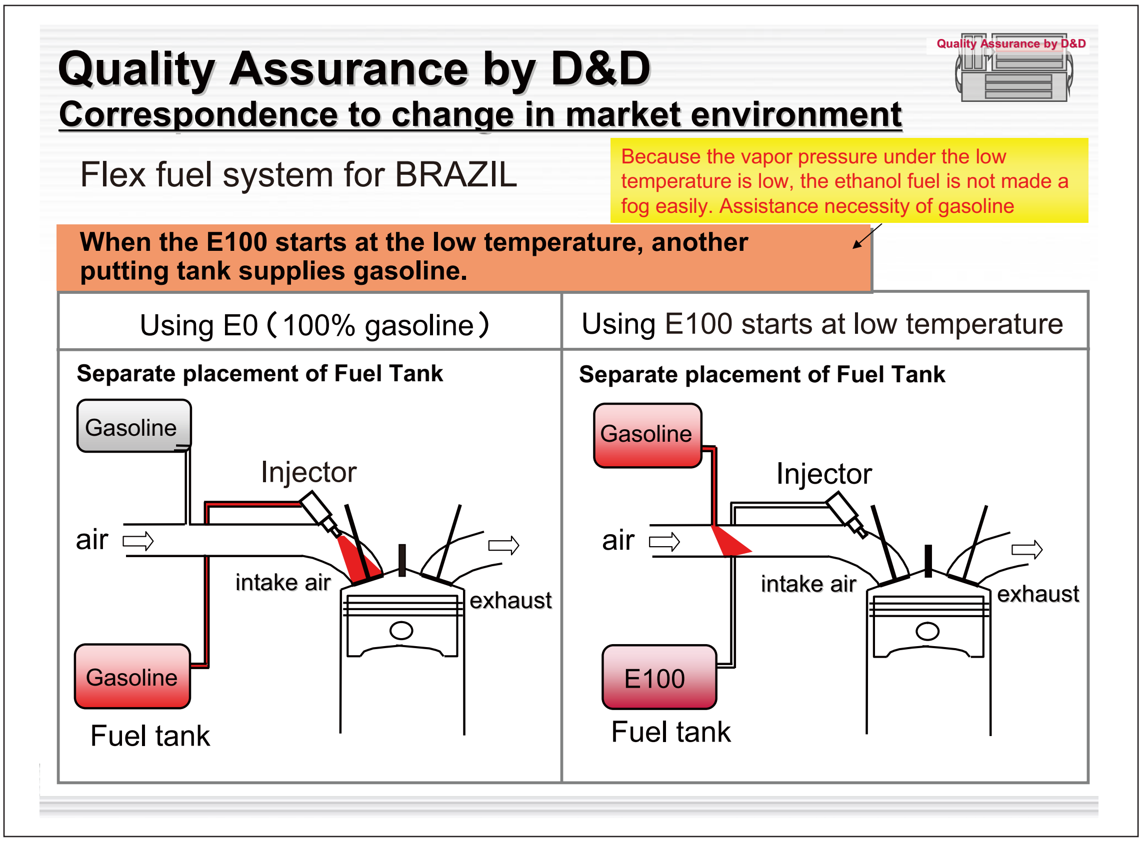
SOS: Start of Sales

Quality Assurance by D&D



RS:Recall and Service campaign
D&D: Design and Development

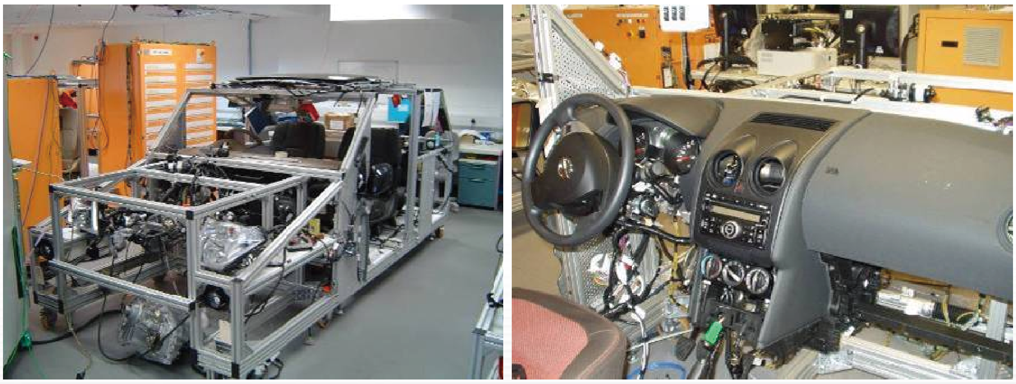

Quality Assurance by D&D
Quality Assurance by D&D
Correspondence to change in market environment
Trend of ethanol fuel
①Standard value
②Market share of blended fuel
③Max concentration
④Average blended concentration
: Country/region without standard (restriction)/information on ethanol
: Country/region with standard of E10 or less(restriction)
: Country/region with standard of E10 or more(restriction)
SWEDEN ①E5 ②63% (all premium) ③4.9% ④3% (n=8) ①E85 ①E95
EU ①E5
POLAND ①E5 ②40% ③4% ④3.8% (n=5)
TANZANIA, ZAMBIA ①E10
MALAWI ③24%
SOUTH AFRICA ①E10
CHINA ①E10±2?⇒E15 ②20% (n=195)
JAPAN ①E3
THAILAND ①E10 ＊2010~:E20
INDIA ①E10
AUSTRALIA ①E10 ②33% ③10.8% ④10.4% (n=8)
PARAGUAY ①E18 ②100% ③15.7% ④11.9% (n=8)
COLUMBIA ①E10
ARGENTINA ①E5
CANADA ①E10 ②6.5% ③9.9% ④9.6% (n=46)
US ①E10 ②28% ③10.3% ④9.2% (n=402) ①E85 ②2%? ③85% ④85%
BRAZIL
①E22 ②84% ③26.4% ④25.4% (n=16)
①E100 ②16% ③93.8% ④93.2%


Quality Assurance by D&D
Quality Assurance by D&D
Correspondence to change in market environment
Flex fuel system for BRAZIL
Because the vapor pressure under the low temperature is low, the ethanol fuel is not made a fog easily. Assistance necessity of gasoline
When the E100 starts at the low temperature, another putting tank supplies gasoline.
Using E0（100% gasoline）
Using E100 starts at low temperature
Separate placement of Fuel Tank
Gasoline
Injector
air
intake air
exhaust
Gasoline
Fuel tank
Separate placement of Fuel Tank
Gasoline
Injector
air
intake air
exhaust
E100
Fuel tank

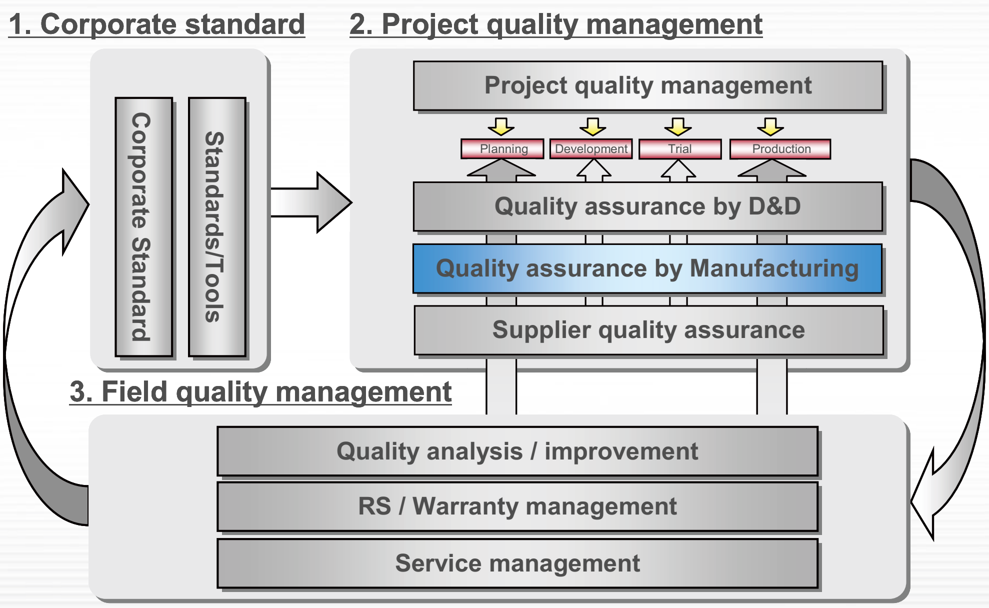
Quality Assurance by D&D

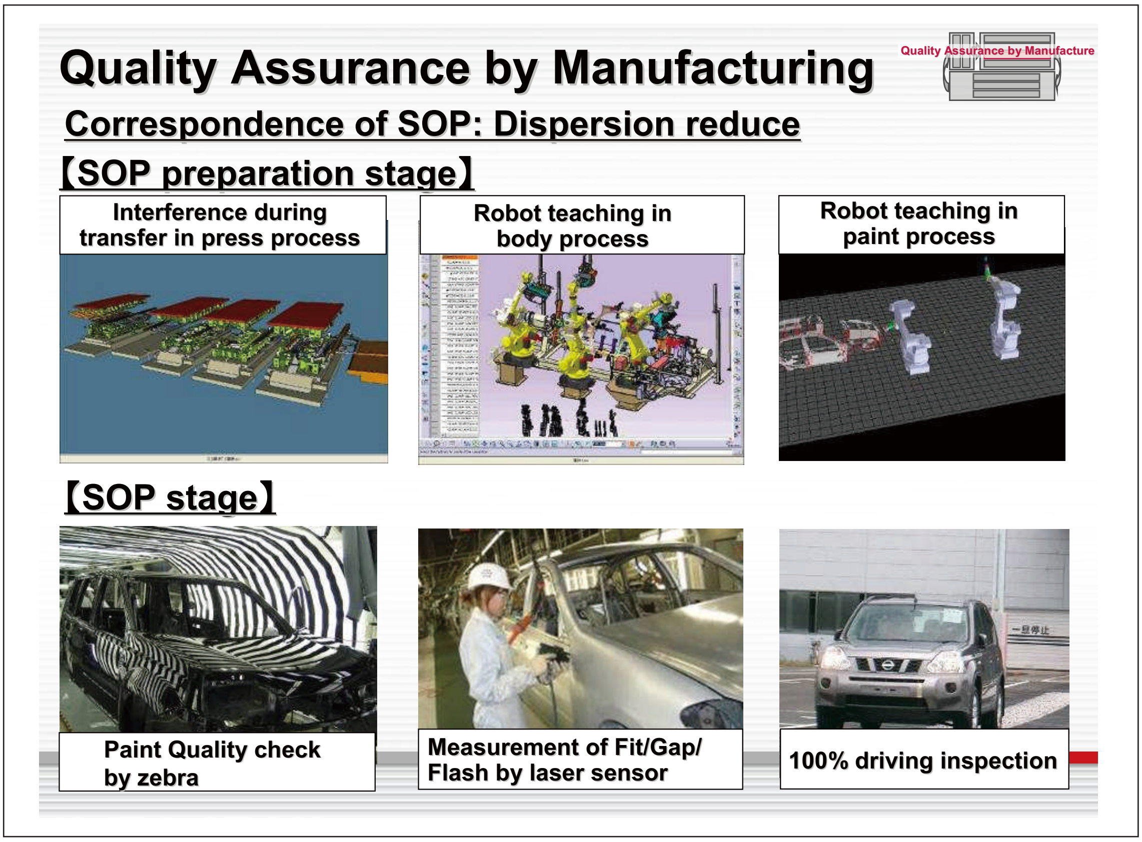
Corresponding the customer usage:
EIPF (Electrical Integration PlatForm)

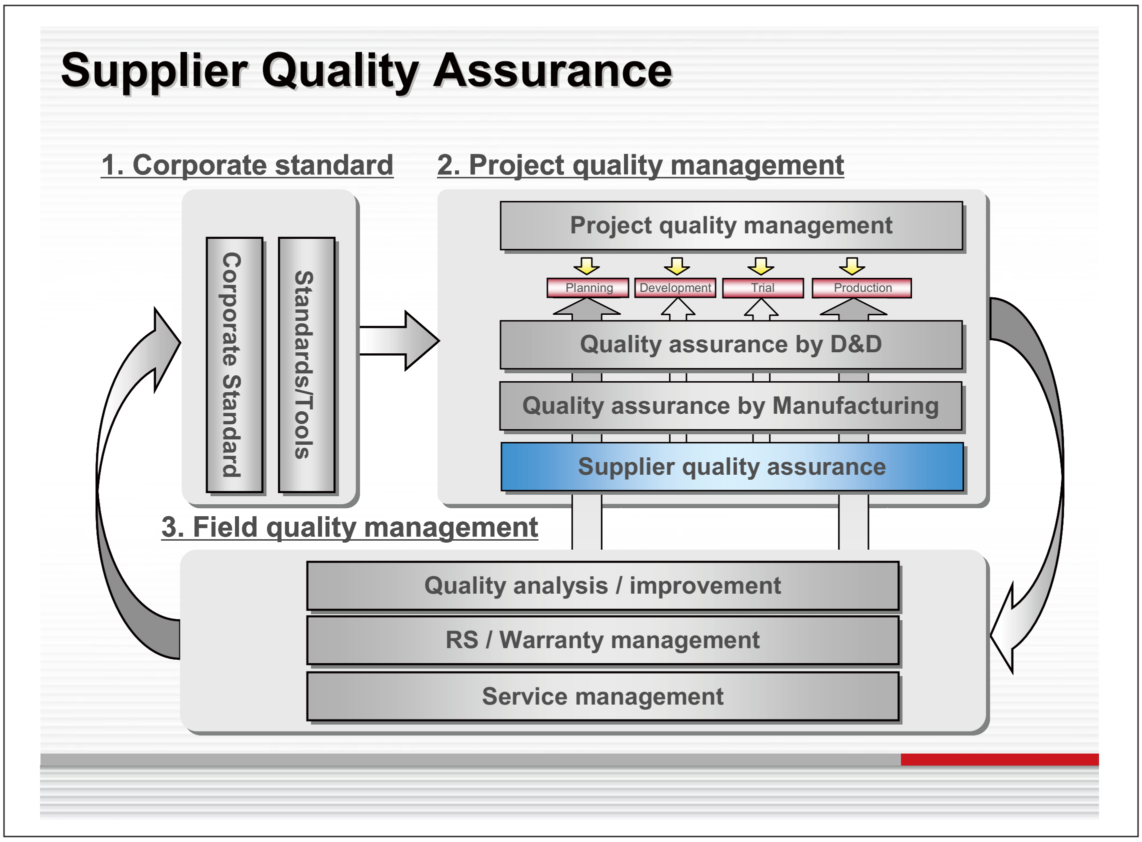
"The check system which does not over look a program bug in the Electron/Electrical complicated circuit "



Quality Assurance by Manufacturing




Quality Assurance by Manufacturing
Quality Assurance by Manufacture
Correspondence of SOP: Dispersion reduce
【SOP preparation stage】
Interference during transfer in press process
Robot teaching in body process
Robot teaching in paint process
【SOP stage】
Paint Quality check by zebra
Measurement of Fit/Gap/ Flash by laser sensor
100% driving inspection


Supplier Quality Assurance
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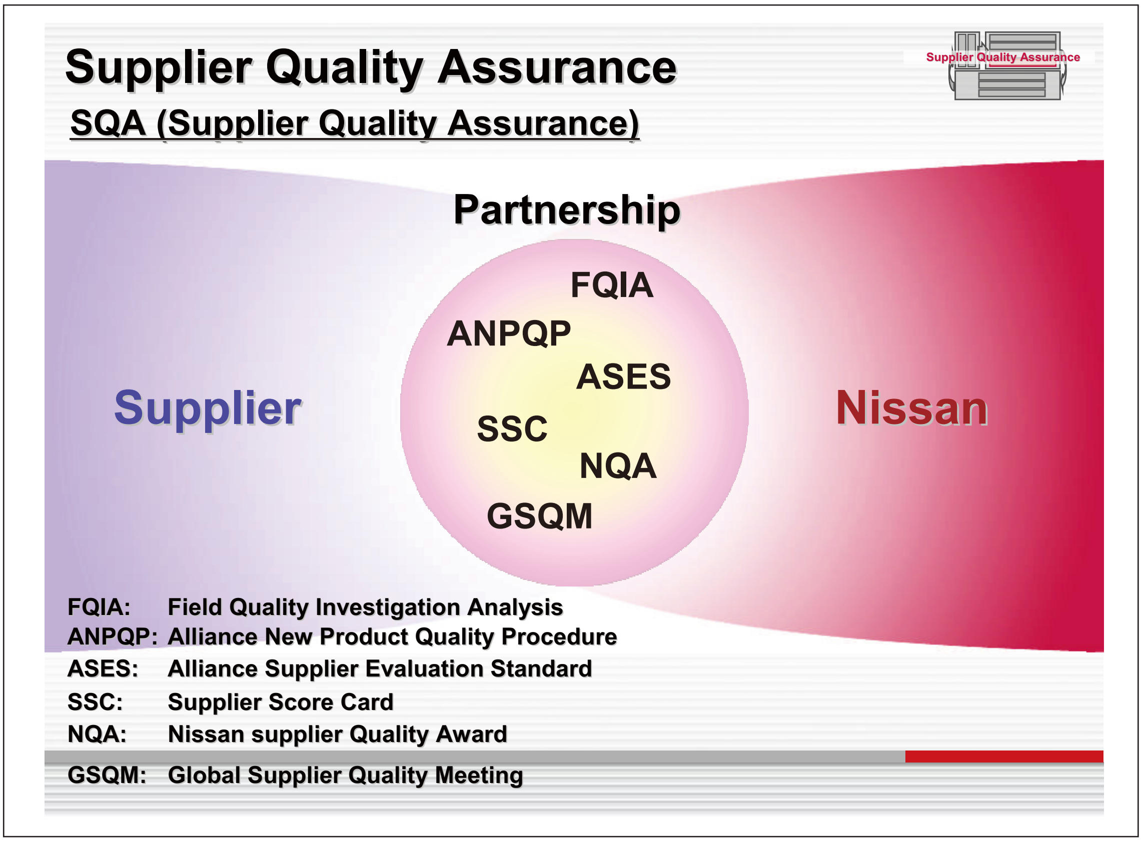
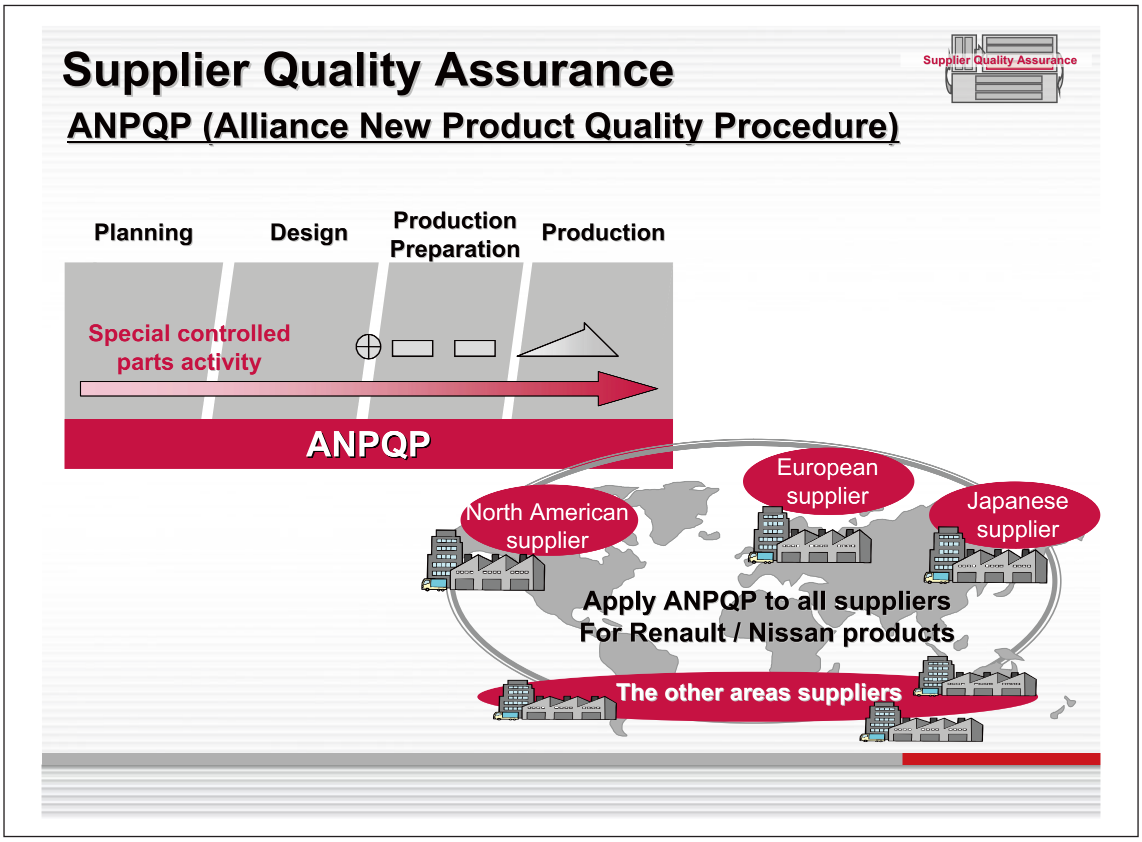

Supplier Quality Assurance
SQA (Supplier Quality Assurance)
Supplier Quality Assurance
Partnership
Supplier
Nissan
FQIA
ANPQP
ASES
SSC
NQA
GSQM
FQIA: Field Quality Investigation Analysis
ANPQP: Alliance New Product Quality Procedure
ASES: Alliance Supplier Evaluation Standard
SSC: Supplier Score Card
NQA: Nissan supplier Quality Award
GSQM: Global Supplier Quality Meeting


Supplier Quality Assurance
ANPQP (Alliance New Product Quality Procedure)
Supplier Quality Assurance
Planning
Design
Production Preparation
Production
Special controlled parts activity
ANPQP
European supplier
North American supplier
Japanese supplier
Apply ANPQP to all suppliers
For Renault / Nissan products
The other areas suppliers

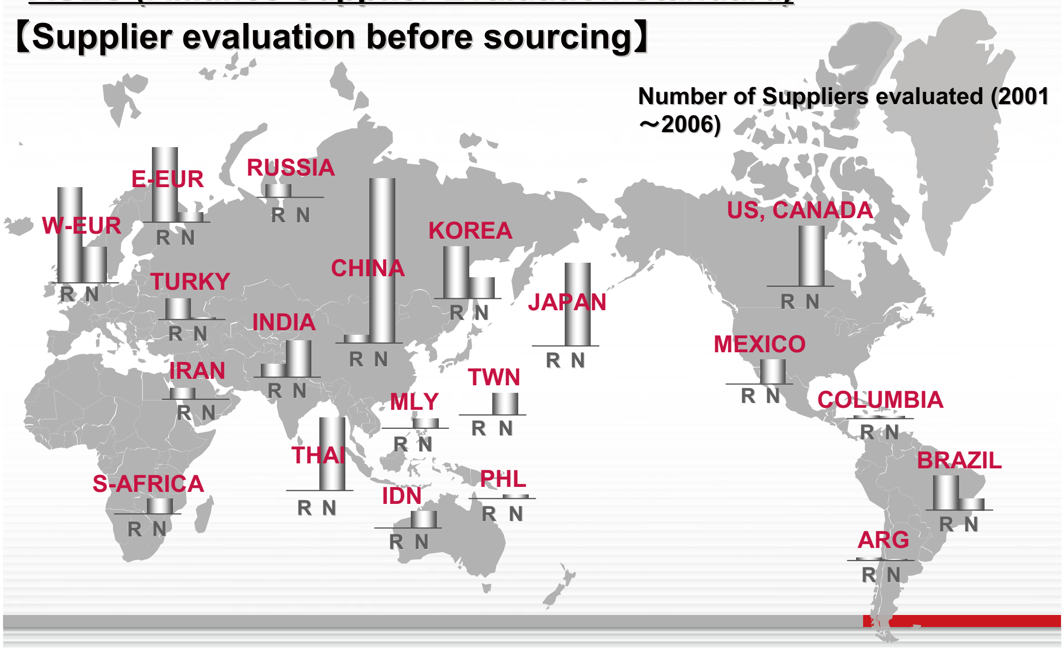
Supplier Quality Assurance

Supplier Quality Assurance

ASES (Alliance Supplier Evaluation Standard)

【Supplier evaluation before sourcing】

Number of Suppliers evaluated (2001～2006)



Supplier Quality Assurance

Supplier Quality Assurance

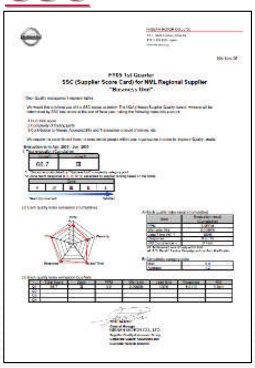
SSC: Supplier Score Card

【Supplier evaluation after sourcing】

The one that supplier's quality performance was evaluated based on each quality index.

Evaluation item
Delivery quality (PPM)
Field Quality (Warranty)
Countermeasure period (Lead time)
Response
Important Quality problem (R/S)

SSC



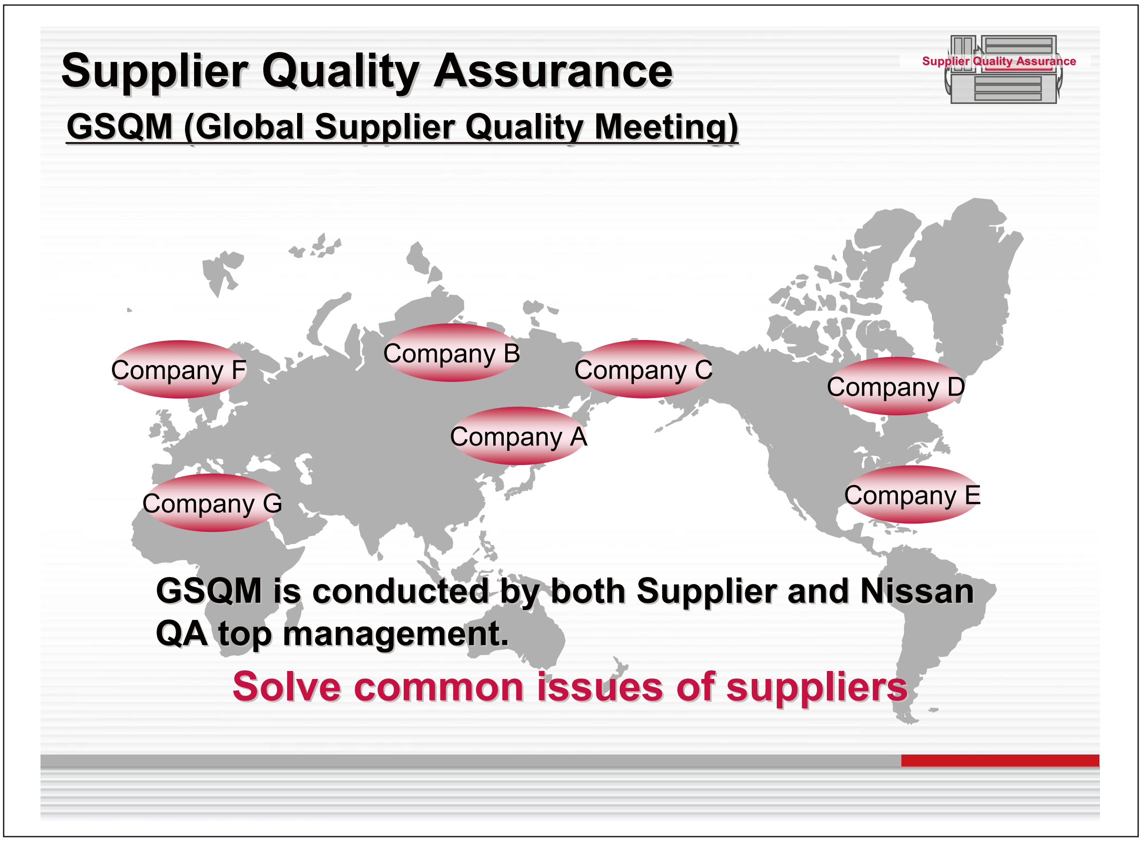
Supplier Quality improvement activity

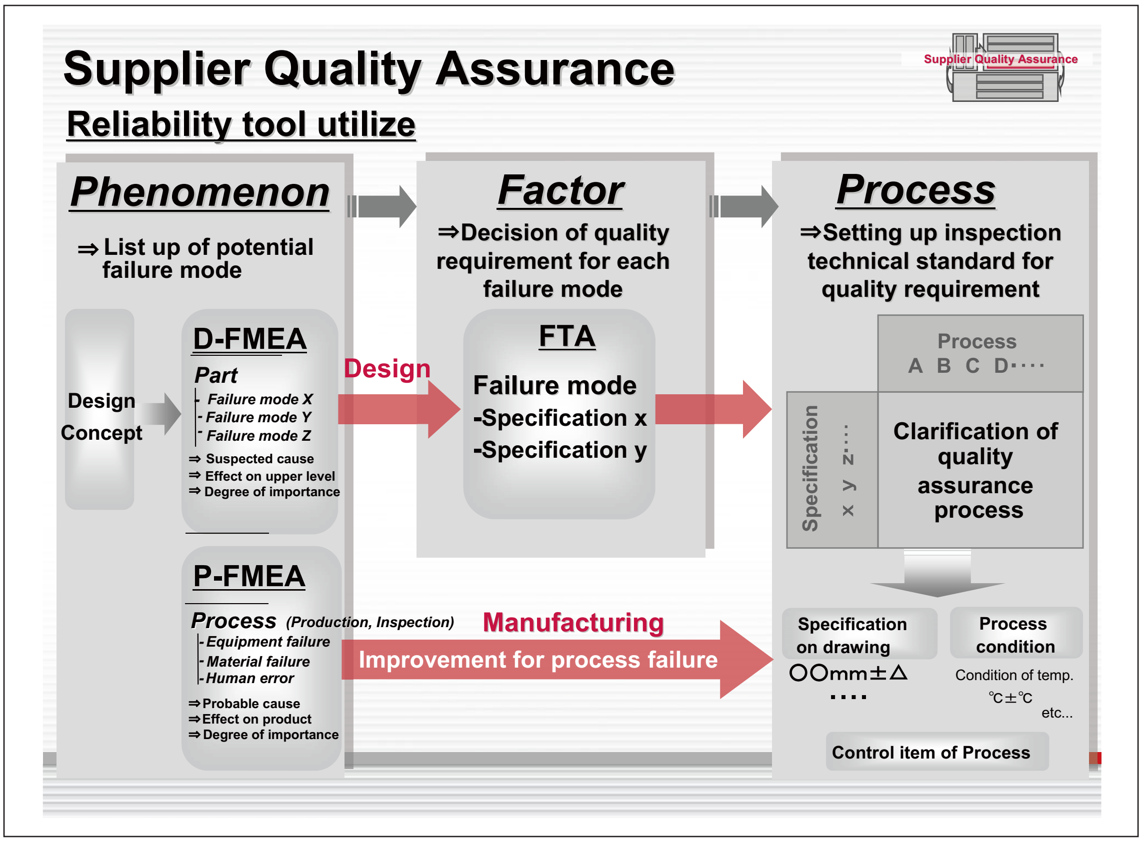
Sourcing information

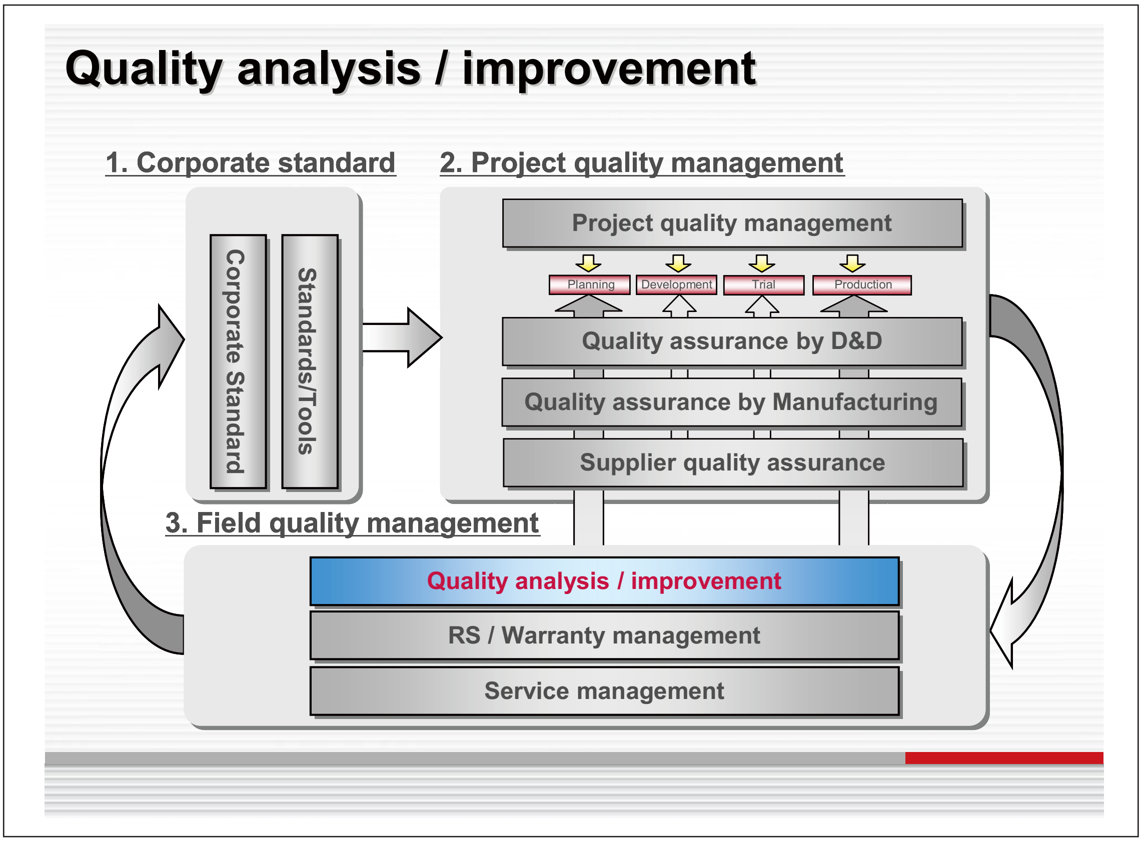
Nissan Quality Award(NQA)

Excellent supplier

SSC=Supplier Score card
PPM=Parts Per Million


Supplier Quality Assurance
GSQM (Global Supplier Quality Meeting)
Supplier Quality Assurance
Company F
Company B
Company C
Company D
Company A
Company G
Company E
GSQM is conducted by both Supplier and Nissan QA top management.
Solve common issues of suppliers


Supplier Quality Assurance
Reliability tool utilize
Supplier Quality Assurance
Phenomenon
⇒List up of potential failure mode
Design Concept
D-FMEA
Part
Failure mode X
Failure mode Y
Failure mode Z
⇒ Suspected cause
⇒ Effect on upper level
⇒ Degree of importance
P-FMEA
Process (Production, Inspection)
Equipment failure
Material failure
Human error
⇒Probable cause
⇒Effect on product
⇒Degree of importance
Design
Factor
⇒Decision of quality requirement for each failure mode
FTA
Failure mode
-Specification x
-Specification y
Manufacturing
Improvement for process failure
Process
⇒Setting up inspection technical standard for quality requirement
Process
A B C D····
Specification
x y z····
Clarification of quality assurance process
Specification on drawing
○○mm±△
····
Process condition
Condition of temp.
℃±℃
etc...
Control item of Process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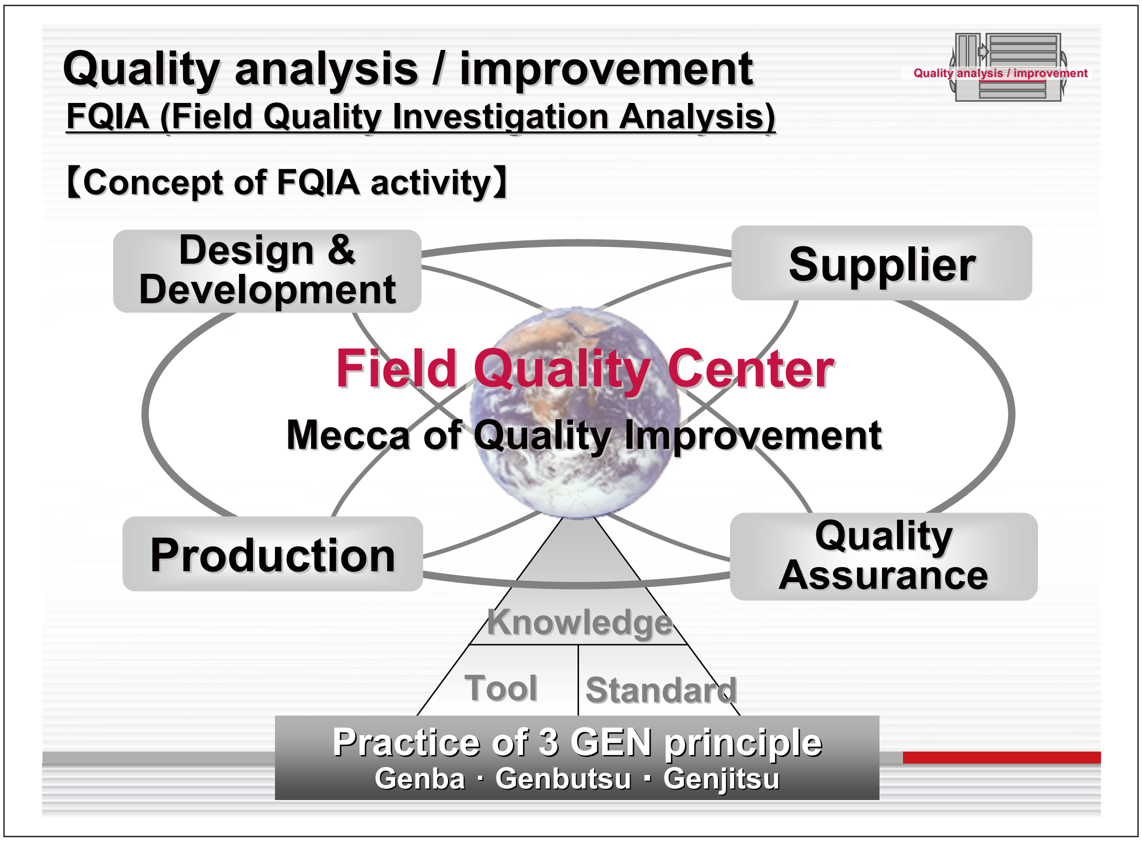
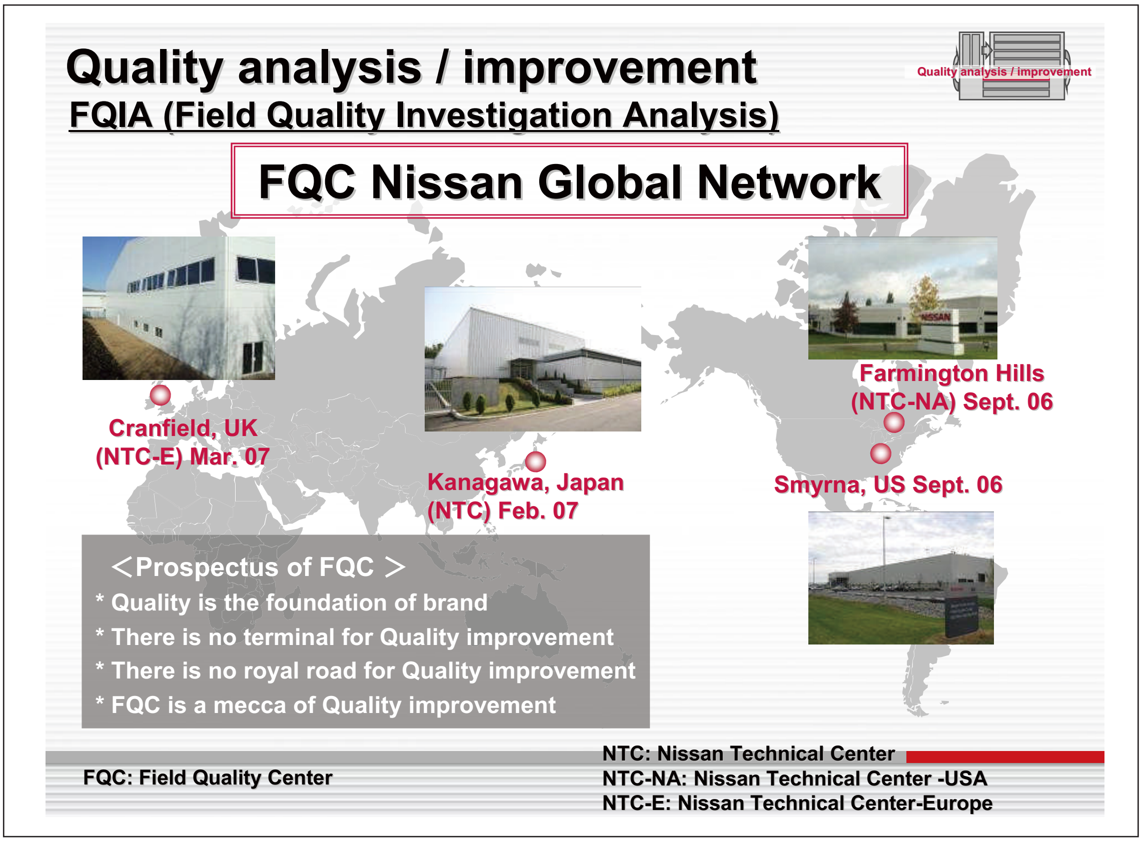
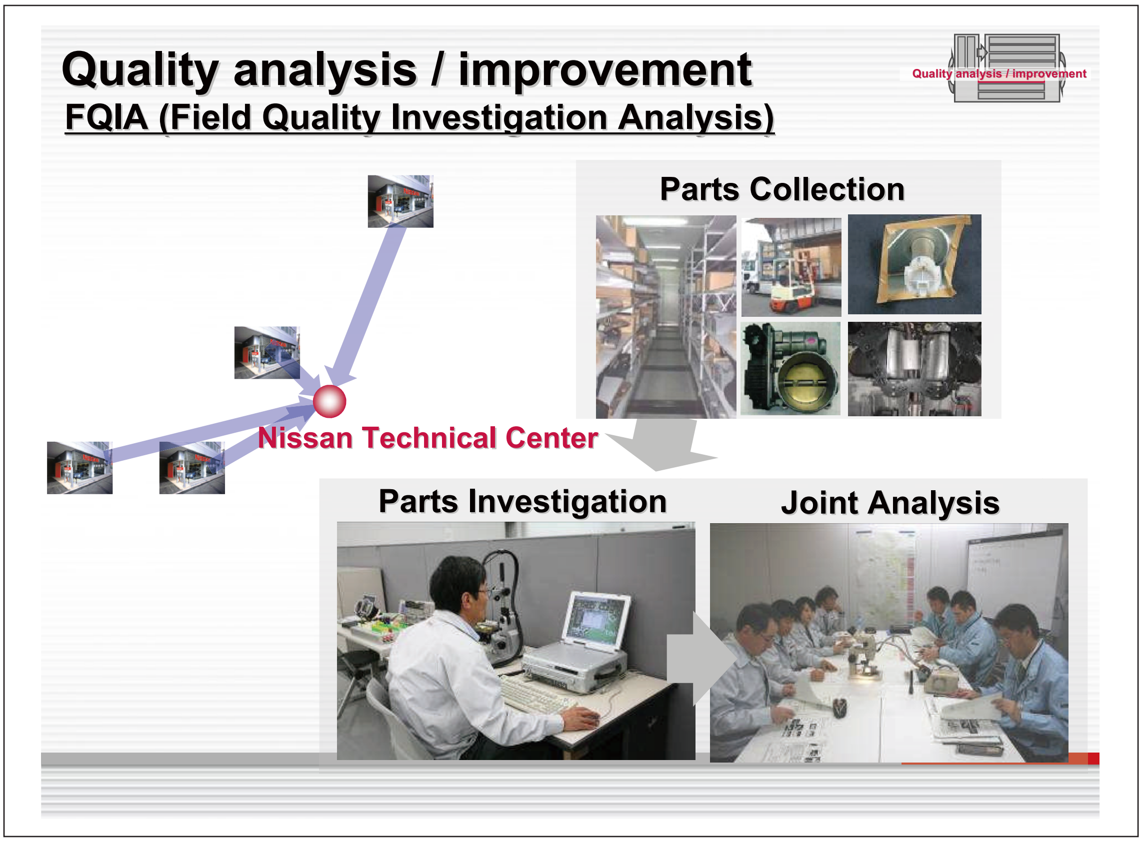
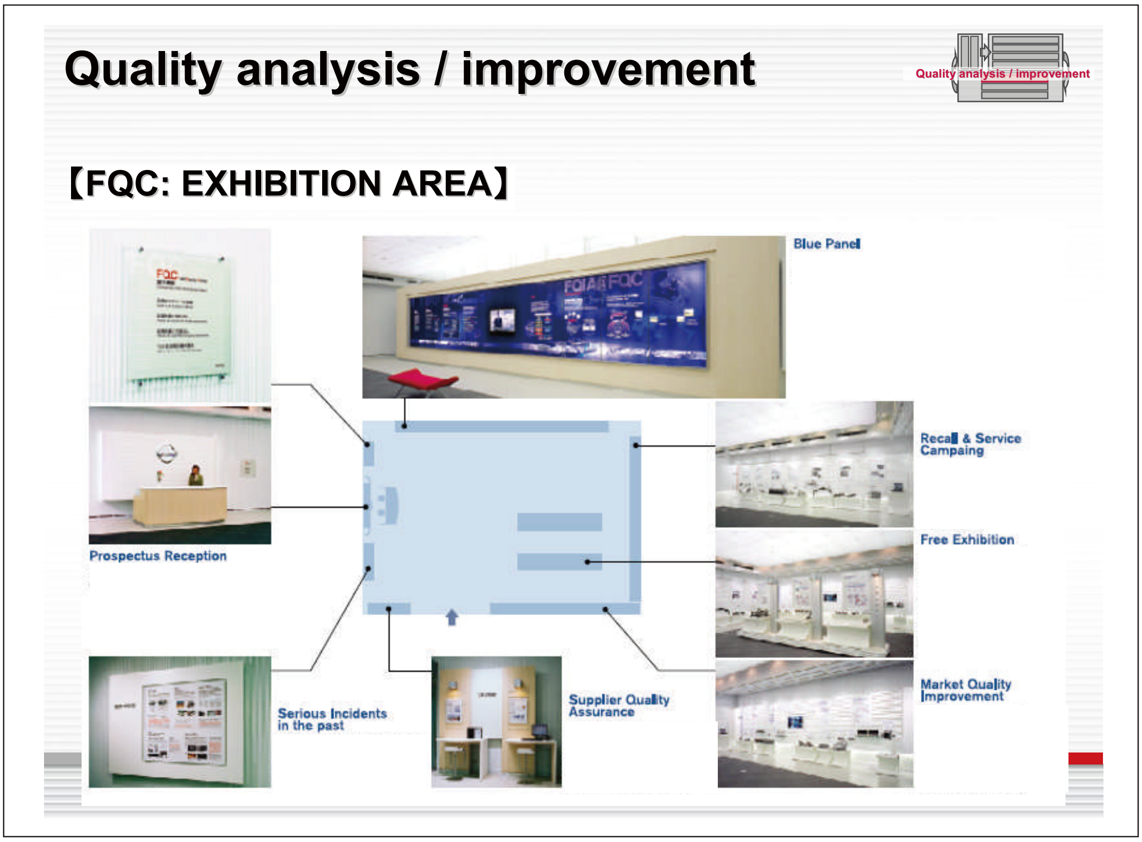
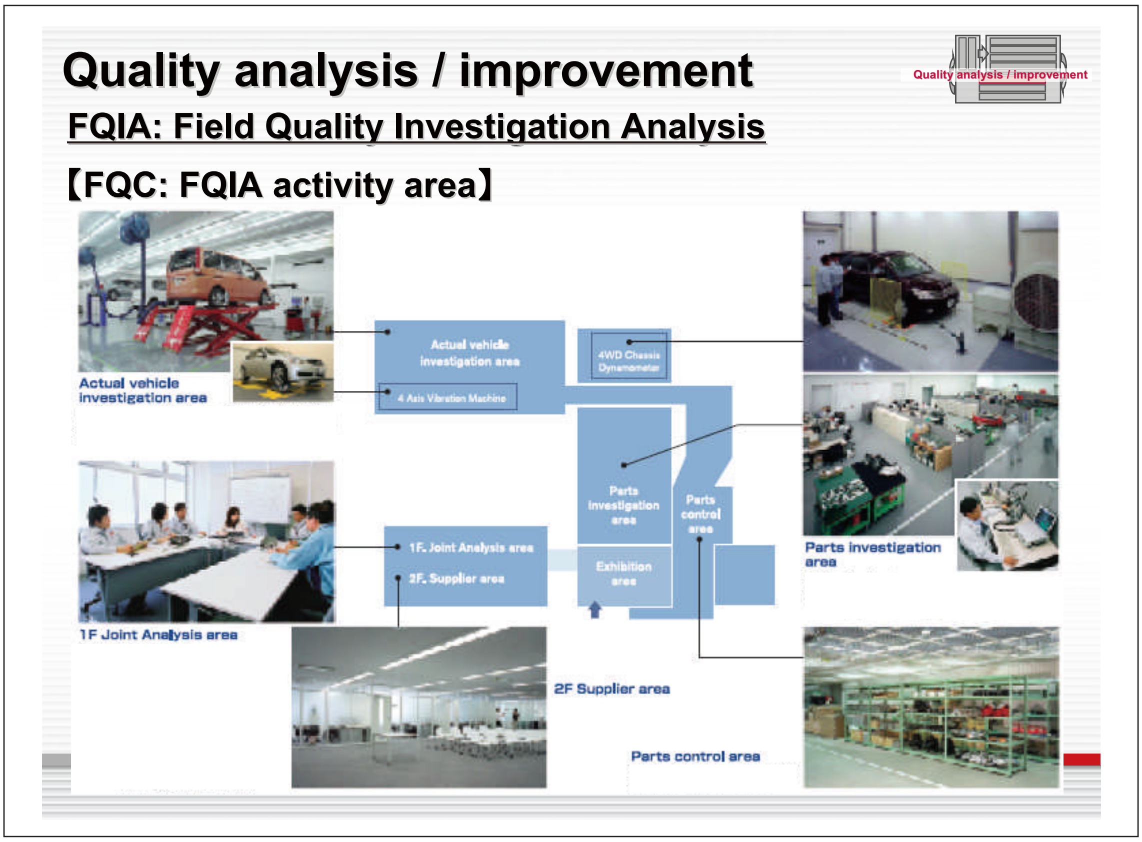
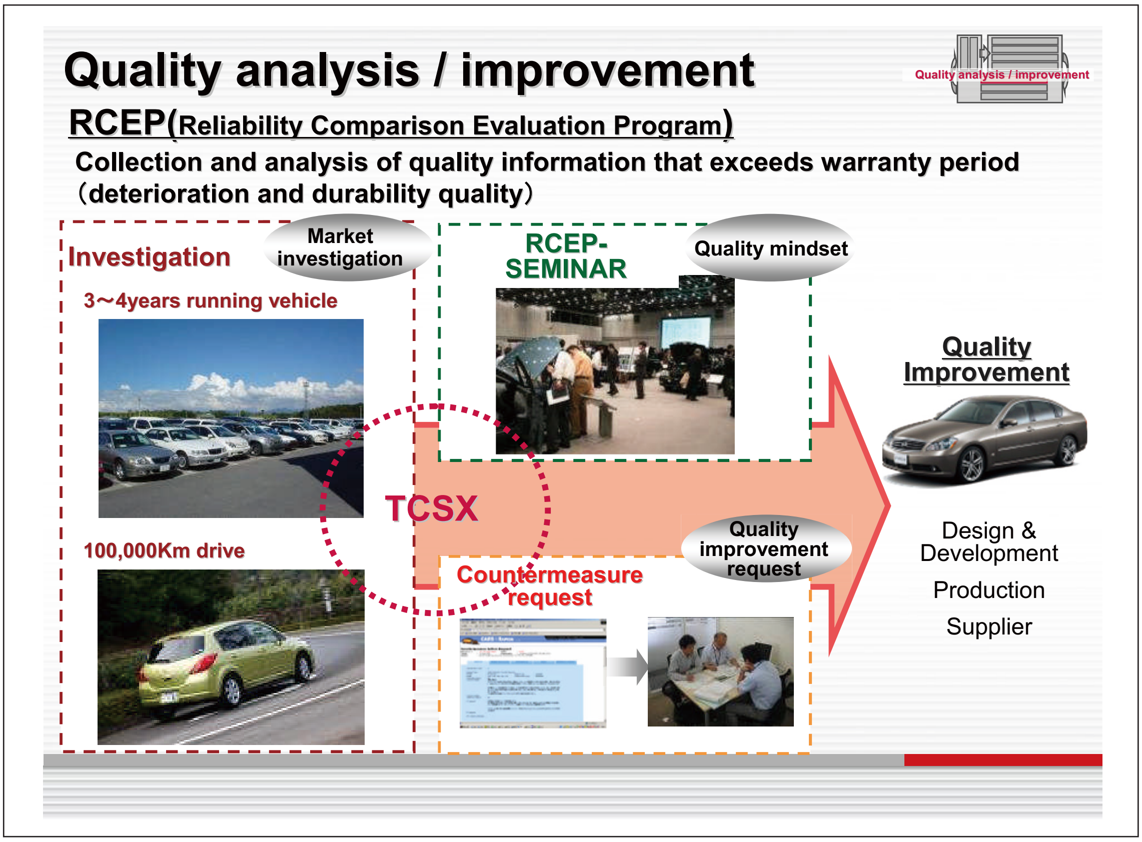

Quality analysis / improvement
FQIA (Field Quality Investigation Analysis)
【Concept of FQIA activity】
Quality analysis / improvement
Design & Development
Supplier
Field Quality Center
Mecca of Quality Improvement
Production
Quality Assurance
Knowledge
Tool
Standard
Practice of 3 GEN principle
Genba · Genbutsu · Genjitsu


Quality analysis / improvement
FQIA (Field Quality Investigation Analysis)
Quality analysis / improvement
FQC Nissan Global Network
Cranfield, UK
(NTC-E) Mar. 07
Kanagawa, Japan
(NTC) Feb. 07
Farmington Hills
(NTC-NA) Sept. 06
Smyrna, US Sept. 06
＜Prospectus of FQC ＞
* Quality is the foundation of brand
* There is no terminal for Quality improvement
* There is no royal road for Quality improvement
* FQC is a mecca of Quality improvement
FQC: Field Quality Center
NTC: Nissan Technical Center
NTC-NA: Nissan Technical Center -USA
NTC-E: Nissan Technical Center-Europe

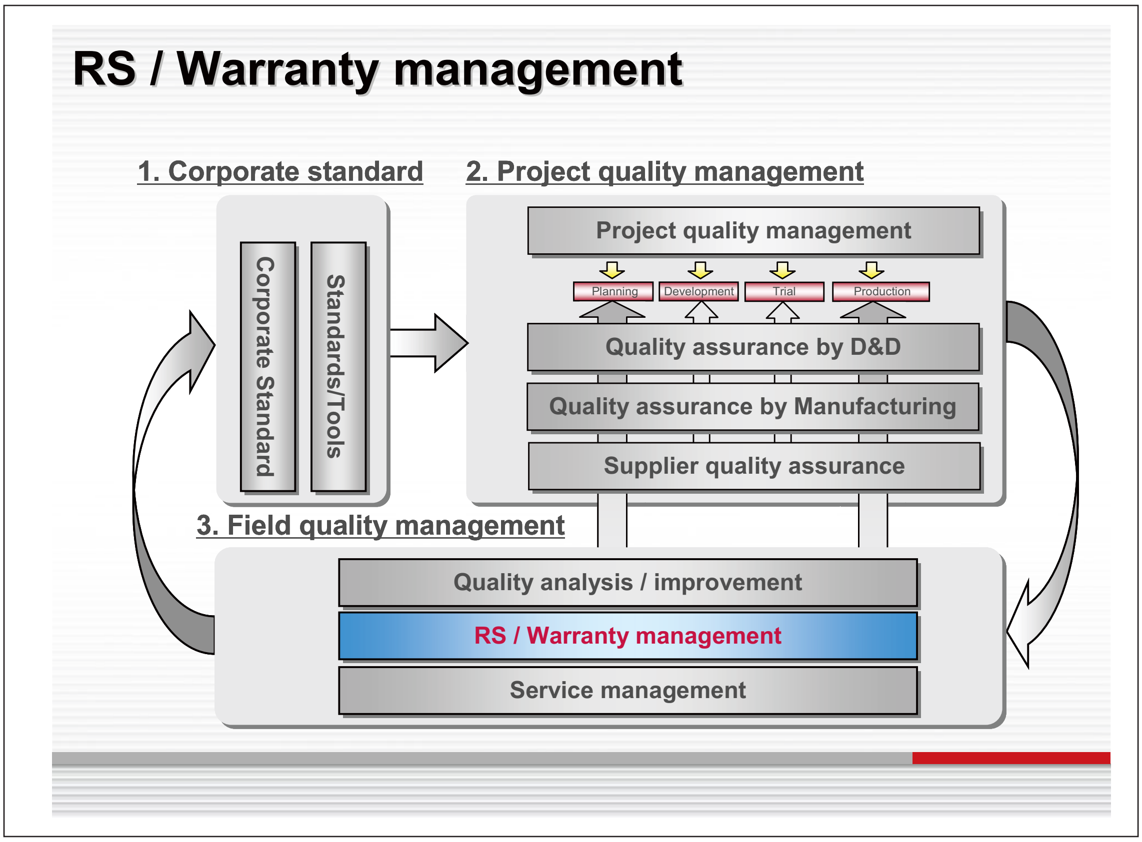

Quality analysis / improvement
FQIA (Field Quality Investigation Analysis)
Quality analysis / improvement
Parts Collection
Nissan Technical Center
Parts Investigation
Joint Analysis


Quality analysis / improvement
Quality analysis / improvement
【FQC: EXHIBITION AREA】
Blue Panel
Prospectus Reception
Recall & Service Campaing
Free Exhibition
Serious Incidents in the past
Supplier Quality Assurance
Market Quality Improvement


Quality analysis / improvement
Quality analysis / improvement
FQIA: Field Quality Investigation Analysis
【FQC: FQIA activity area】
Actual vehicle investigation area
Actual vehicle investigation area
4 Axis Vibration Machine
4WD Chassis Dynamometer
Parts investigation area
Parts control area
Exhibition area
1F. Joint Analysis area
2F. Supplier area
Parts investigation area
1F Joint Analysis area
2F Supplier area
Parts control area



Quality analysis / improvement
Quality analysis / improvement
RCEP(Reliability Comparison Evaluation Program)
Collection and analysis of quality information that exceeds warranty period
(deterioration and durability quality)
Investigation
Market investigation
3~4years running vehicle
100,000Km drive
RCEP-SEMINAR
Quality mindset
TCSX
Countermeasure request
Quality improvement request
Quality Improvement
Design & Development
Production
Supplier



RS / Warranty management
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Service management

Product attractiveness quality

PQ: Perceived Quality

Definition of PQ

The pleasure of looking, touching and operating by customers

Luxury High Quality

- Good Looking
- Fit and Finish
- Operating Quality

Amenity Comfort Easiness

- Cozy touch and Sound
- Seat Comfort

Product attractiveness quality

PQ: Perceived Quality (Sensibility quality)

Product attractiveness quality

PQ: Perceived Quality (Sensibility quality)

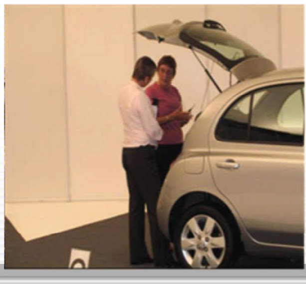
Product attractiveness quality

PQ: Perceived Quality (Sensibility quality)

Product attractiveness quality

PQ: Perceived Quality (Sensibility quality)

- **Evaluation of PQ**
  Evaluation and validation of over 800 customer view point from the time of design process.
- **PQ after launch survey**
  Survey is conveyed at the launched market with the aim to reflect the results to the next model and validation of target achievement level of SOP models.




Contents

- Management situations surrounding quality
- Quality improvement activities
- **Ending remarks**

Ending Remarks
Growth of Royal Customer Cycle

Uninterrupted of Royal Customer Cycle creation

NISSAN

Value-Up

COTS Policy & "Space on Demand" in Japan

2007.10.29

SAEKI, Norihiko

Deputy Director
Aerospace and Defense Industry Division
Manufacturing Industries Bureau
Ministry of Economy Trade and Industry
(METI)

saeki-norihiko@meti.go.jp

三度炊く 飯さえ硬し 軟らかし 思うままには ならぬ世の中
'We never cook rice satisfactorily even if staple food'

北大路魯山人
"Kitaohji, Rosanjin," a famous Japanese gourmet

'We have met the enemy--he is us.'
（我々は敵に出会った。それは我々だった。）

Walt Kelly
ウォルトケリー、 画家

1. METI's role in Japanese Space Policy

経済産業省 Ministry of Economy, Trade and Industry METI

a. METI's Role

Generally speaking, METI's industrial policy covers all of the corporate/ Market activities which don't fall within the scope of any organizations of GOJ. As to the space policy, METI's role includes but isn't limited to:

- Maximization of space utilities for global consumers
- Enhancement of efficiency of industrial activities related to space
- Improvement of business environment and/or innovation system for space related activities
- Set up the "Roadmap of Space Technologies" to introduce investment in space activities
- Development of key technologies for space (remote sensing/re-entry/microgravity experiment/launching etc.)
- Standardization of space technologies
- Ensure effective Export control of space components & technologies

b. Chronology

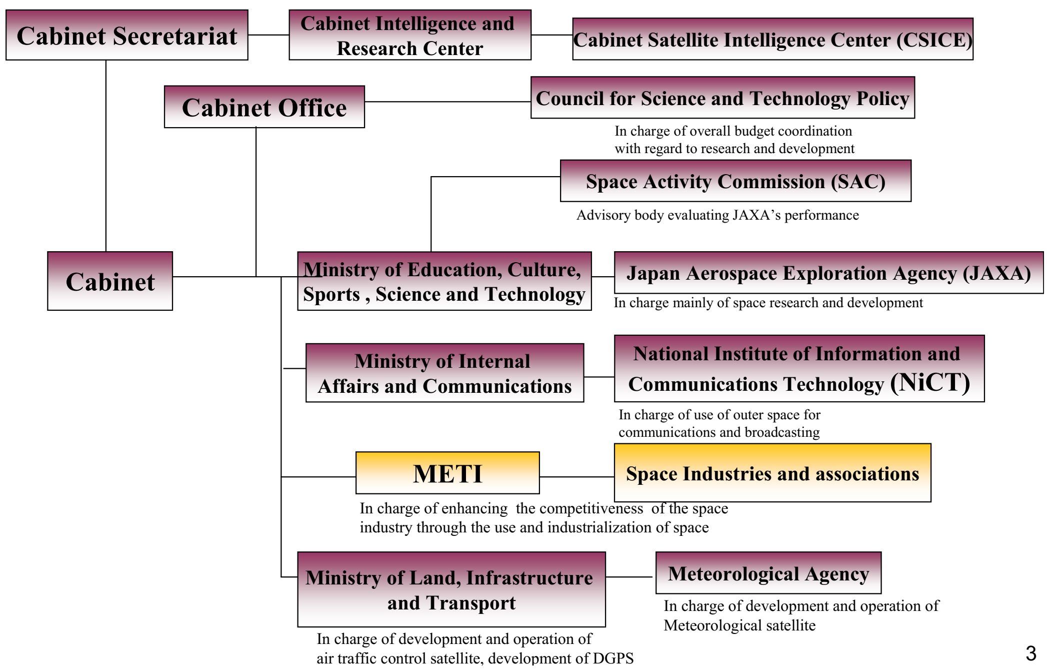
1979 "Space Industry Office" established
1987 "Space Industry Division" upgraded
1997 "Aerospace and Defense Division" converted

2

1. METI's role in Japanese Space Policy

経済産業省 Ministry of Economy, Trade and Industry METI

(chart 1) Organization related to space in Japan

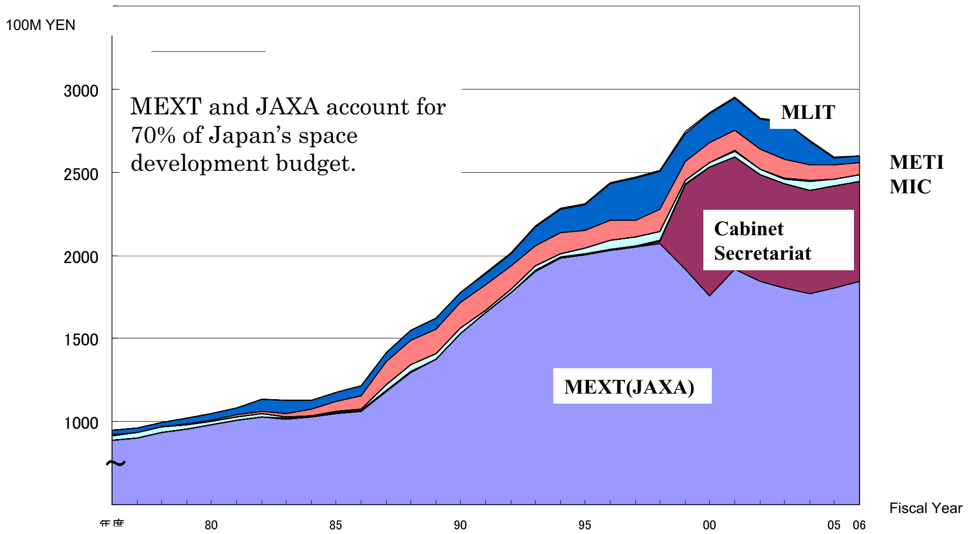


3

1. METI's role in Japanese Space Policy

経済産業省 Ministry of Economy, Trade and Industry METI

(chart 2) Trend of Japanese government expenditure



MEXT: Ministry of Education, Culture, Sports , Science and Technology
MIC : Ministry of Internal Affairs and Communication
METI: Ministry of Economy, Trade and Industry
MLIT: Ministry of Land, Infrastructure and Transport

4

2. Overview of METI's previous projects

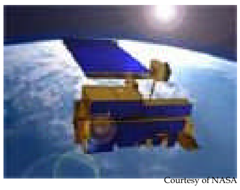
経済産業省 Ministry of Economy, Trade and Industry METI

a. Remote Sensing– METI's Sensors

JERS-1 Project
<Japanese Earth Resources Satellite-1>
[JAXA (former NASDA)]
(1981-2003)

ADEOS Project
<Advanced Earth Observing Satellite>
[JAXA (former NASDA)]
(1989-1997)

TERRA Project
[NASA]
(1987-)



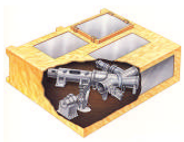
OPS
<Optical Sensor >

SAR
<Synthetic Aperture Radar>

<OPS>
VNIR: 3band, 18x24m@60X60km
NEC
SWIR: 4band, 18x24m@60x60km
NEC

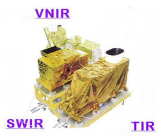
<SAR>
L-band SAR, 18m@75x75km
Polarimetry: HH
Mitsubishi Electric

IMG
<Interferometric Monitor for Greenhouse Gases>



<IMG Sensor>
Fourier Transform Infrared Radiometer
based on Michelson interferometer
for Metan gas
Toshiba

ASTER
<The Advanced Spaceborne Thermal Emission and Reflection radiometer>



<VNIR>
3band, 15m@60X60km
NEC
<SWIR>
6band, 30m@60x60km
Mitsubishi Electric
<TIR>
5band, 90m@60x60km
Fujitsu

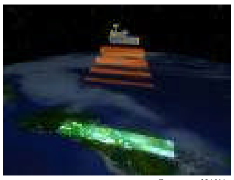
5

2. Overview of METI's previous projects

経済産業省 Ministry of Economy, Trade and Industry METI

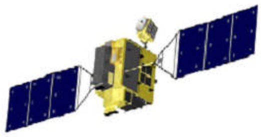
a. Remote Sensing Projects (Cont'd)

ALOS Project
<Advanced Land Observing Satellite>
[JAXA]
(1987-)



Courtesy of JAXA

Disaster Monitoring Project
[JAXA]
(2008-<T.B.D.>)

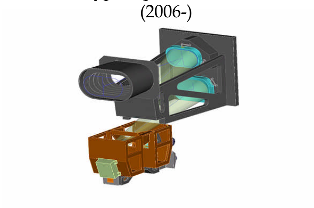


Courtesy of JAXA

PALSAR
<Phased Array type L-band Synthetic Aperture Radar>

< L-band SAR>
10-100m@70x70km-350x350km
Polarimetry (HH, VV, HH+HV, VV+VH, HH+HV+VH+VV)
Mitsubishi Electric

Hyper Spectral Sensor
(2006-)



<Hyper Spectral Sensor>
185 band (400～2500nm), 15m@15x15km
NEC
<Multi Spectral Sensor (VNIR)>
4 band, 5m@90x90km
NEC

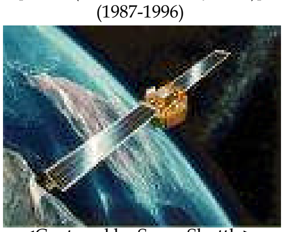
6

2. Overview of METI's previous projects

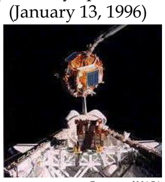
经済産業省 Ministry of Economy, Trade and Industry METI

b. Microgravity experiments & Re-entry technologies

SFU Project
<Space Flyer Unit >
[JAXA (former NASDA/ISAS)]
(1987-1996)

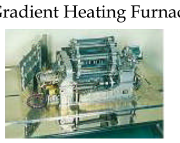


<Captured by Space Shuttle>
(January 13, 1996)



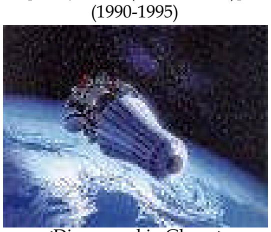
Courtesy of NASA

< Gradient Heating Furnace >



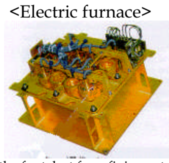
GaAs by Bridgeman method etc.

EXPRESS Project
<EXPeriment RE-entry Space System>
[DLR/JAXA (former ISAS)]
(1990-1995)



<Discovered in Ghana>
(January, 1995)
(after failure of orbit insertion)

<Electric furnace>



Crystalgrowth of catalyst for refining petroleum

USERS Project
<Unmanned Space Experiment Recovery System>
(1996-2005)

<Captured in Pacific Ocean>
(May 29, 2003)

<Gradient Heating Furnace>

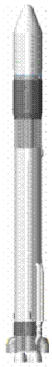
Super-conductor Material Processing Experiment

7

2. Overview of METI's previous projects

経済産業省 Ministry of Economy, Trade and Industry

c. Access to Space – GX rocket Project



[Specification]

- Payload up to 4.4t / LEO
- Total Length 48m
- Total Mass 210t
- First Stage LOX / Kerosene (RD-180)
- Second Stage LOX / LNG

[R&D Co-operation]

METI
- Development of Total Vehicle Design System
- Development of Avionics

MEXT/JAXA
- Development of LNG/LOX Propulsion for 2nd Stage
- Development of Overall Launch Facilities

GALAXY Express Corp.
- Total System Integration
- Development of 1st Stage with application of Atlas-III 1st Stage
- Fairing Development･Development of GX unique facilities

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2. Overview of METI's previous projects

経済産業省 Ministry of Economy, Trade and Industry

d. Standard satellite bus/Other key technologies

(1)LEO Standard Bus

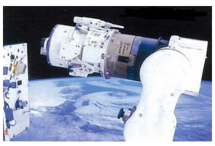
USERS (1996-2005)

SERVIS 1 (1999-)

SERVIS 2 (1999-)

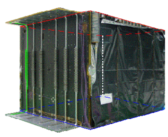
(2)Key technologies (Just examples)

<Robot Hand>

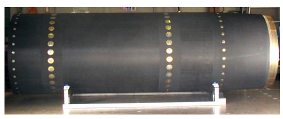


Precise robot hand on millimeter scale

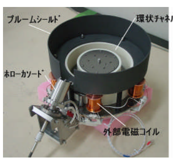
<3D heat pipe system>



<Advanced CFRP for satellite body>

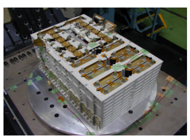


<Hall thruster >



200 mN thruster

<Lithium ion battery for space>



<Star Sensor based on COTS technology>

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3. COTS policy in METI

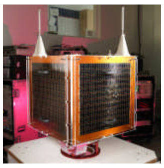
a. METI (former MITI) has highlighted the importance of applications of COTS technologies in space because COTS technologies can ensure:

--application of cutting edge technologies
--stable supply of parts and technologies
--short term delivery
--low cost space systems

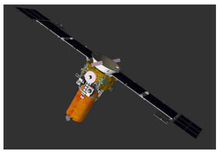
b. Now COTS technologies has been applied to many types of satellite projects which include but are not limited to:

--LEO Communication satellites (ex. Orbcomm)
--Earth Observation satellites (ex. Surry Satellite Technology Ltd.)
--S & T satellites (ex. CNES & NASA etc.)
--Military Satellites (ex. Tacsat Series in US & Israeli satellite series)


Orbcomm series
(c)Orbital Sciences Corp.


Disaster Monitoring Satellite
(c)Surrey Satellite Technology, ltd..


Orbiting Carbon Observatory
(c)Orbital Sciences Corp.


Tacsat-2
(c)MicroSat Systems

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3. COTS policy in METI (Cont'd)

c. METI's Projects related COTS includes

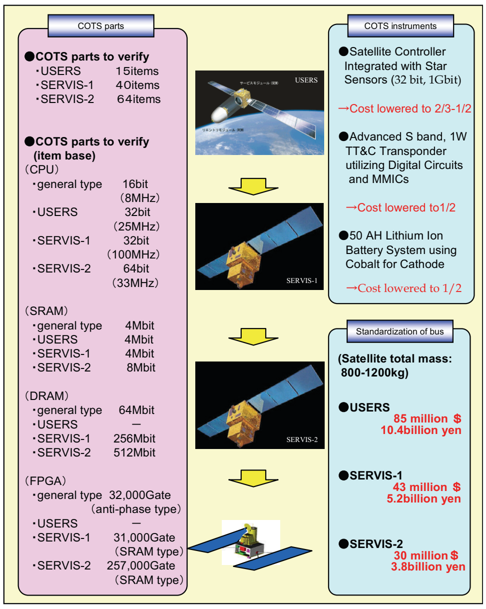
--USERS Project
--SERVIS Project
--SOD Project (see page 14 -)

d. Overview of USERS/SERVIS projects produce:

--Guidelines for COTS parts application
Database for COTS parts & technologies
--Application of COTS instruments for space flight
--Satellite standard bus

e. Outcome of USERS/SERVIS projects

1) Cost of satellite standard bus lowered to 1/3
2) COTS Database for 211 parts & technologies
(60% of COTS parts are usable for LEO)
3) COTS Parts Evaluation Guidelines
4) Equipment Design Guidelines
(3) & 4) need discussing under ISO)
5) Some of the COTS applied equipments used globally
(ex. Lithium Ion Battery)



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3. COTS policy in METI – SERVIS Project

経済産業省 Ministry of Economy, Trade and Industry METI

Experimental Equipment on SERVIS -1

No.	Equipment	Objective	Developed by
1	**VTS**	Super Plastic Formed Titanium, Surface Tension Type Propellant Tank System with an Expulsion Efficiency of 99.5%	IHI Aerospace 1)
2	**INU**	Integrated Navigation Unit System with GPS Receiver and Star Sensor	NEC/NTSpace 2)
3	**PCDS**	Series Switching Regulator Type Power Control and Distribution System with Peak Power Tracking Function	NEC/NTSpace
4	**APDM**	Advanced Paddle Drive Mechanism with Low Vaporization Vacuum Grease Lubrication	NEC/NTSpace
5	**ATTC**	Advanced S band, 1W TT&C Transponder utilizing Digital Circuits and MMICs	NEC/NTSpace
6	**OBC**	32 bit On Board Computer with a Card-size Multi-chip Module	Mitsubishi Heavy Industries 3)
7	**SIS**	32 bit Satellite Controller Integrated with Star Sensors and Mass Memory of 1Gbits	Mitsubishi Electric Corp. 4)
8	**LIB**	50 AH Lithium Ion Battery System using Cobalt for Cathode	Mitsubishi Electric Corp.
9	**FOIRU**	3-axis Fiber Optic Gyro Inertial Reference Unit	Mitsubishi Precision Co. 5)

Contact Point:1) t-asou@iac.ihi.co.jp, 2) t-kubota@ct.jp.nec.com, 3) t_araki@mhi.co.jp, 4) Aoki.Shunichiro@dh.MitsubishiElectric.co.jp, 5) ttakei@mpcnet.co.jp

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3. COTS policy in METI – SERVIS Project

経済産業省 Ministry of Economy, Trade and Industry METI

Experimental Equipment on SERVIS -2

No.	Equipment	Objective	Developed by
1	**LIBA**	90AH Automotive Lithium Ion Battery system with Manganese for Cathode	IHI Aerospace1)
2	**ADMS**	Advanced 32 bit Data Management System with automobile technology	IHI Aerospace
3	**CRAFT**	64bit Autonomous Fault Tolerant Computer with CRAFT System	NEC/NTSpace2)
4	**PPRTU**	Plug-and-Play Remote Terminal Unit using IEEE 1394 data bus	NEC/NTSpace
5	**HPDC**	8 bit & 12 bit High Performance Data Compressor applying JPEG technology with a speed of 1M pixel/sec	Mitsubishi Heavy Industries3)
6	**APE**	Advanced Position detection Experiment system improving the accuracy of SERVIS orbital position using commercial GPS receivers	Mitsubishi Electric Corp.4)
7	**ASM**	Advanced satellite Structure Module consist of controller and external panel with embedded electric circuit modules and wire harnesses	Mitsubishi Electric Corp.
8	**MBW**	High performance and Low disturbance 30Nms Magnetic Bearing Wheel	Mitsubishi Precision Co.5)
9	**MEMS**	Metal Cantilever type RF MEMS switch with Small RF Loss	Mitsubishi Electric Corp.

Contact Point:1) t-asou@iac.ihi.co.jp, 2) t-kubota@ct.jp.nec.com, 3) t_araki@mhi.co.jp, 4) Aoki.Shunichiro@dh.MitsubishiElectric.co.jp, 5) ttakei@mpcnet.co.jp

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4. New Policy Concept "Space on Demand"

経済産業省 Ministry of Economy, Trade and Industry METI

a. background

(1) Our space systems are just like "Space systems of the space experts, for the space experts, by the experts."
These systems are huge, reliable, complex & hard to use and can be summarized as **"Big Space."**
There is great tendency for the system to be more expensive & closed to inners.

(2) From the view of the space related industries, which are accustomed to this environment, there is great barrier to incentive of seeking cost-benefit, user (except experts)-oriented & efficient systems. Just for example, there is no remote sensing satellite operator in Japanese private sector.

(3) All these things can easily be barrier to introduce investment of outside space industries to space related activities, ensure maximization of benefit for consumers to through industrialization of space.

(4) Therefore METI has decided to restructure the whole space systems, namely, satellite systems, launching systems, ground systems, manufacturing systems & innovation systems.

(5) Finally, we developed the new policy concept of advanced space systems, **"Space on Demand,"** which targets consumer-oriented, efficient & innovative systems.

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4. New Policy Concept "Space on Demand"

経済産業省 Ministry of Economy, Trade and Industry METI

b. "on Demand" means generally…

(a) For consumers

--use anytime & anywhere
--short-term delivery
--low cost
--easy to use
(automated system / easy to train operators / interoperable with general systems)
--easy to fix
--tough & flexible to environmental change

(b) For manufacturers / vendors

--standardization of I/F & basic design concepts
(between components (spacewire/USB2.0) /satellite and launch vehicle/ S/W)
--modularization of components
--standardization of verification process & specification of application

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4. New Policy Concept "Space on Demand"

経済産業省 METI Ministry of Economy, Trade and Industry

c. Principles of "Space on Demand (SOD)"

(a) General Principles

(1) Priority to **replace existing "Big Space"** as much as possible by setting **highest target** and ensuring **low cost** & **short term delivery**

(2) Utilization of **private sector's venture spirit**

(3) **Exploitation of cutting-edge technologies timely** by changing basic design concepts and standardizing space verification process

(4) Close attention to **stable supply** of important parts and technologies

(5) **Adopting COTS technologies**

(b) Principles at system level

(6) Satellite systems: **"Satellite as a Flexible Computer (SFC)" <→see next page>**

(7) Launch vehicle: **quick to launch, all-weather type & flexible to any type of satellite**

(8) Ground systems: **smaller, easier, automated, movable & flexible to any type of satellite**

(9) Verification system: **process standardization & agile application to space assets**

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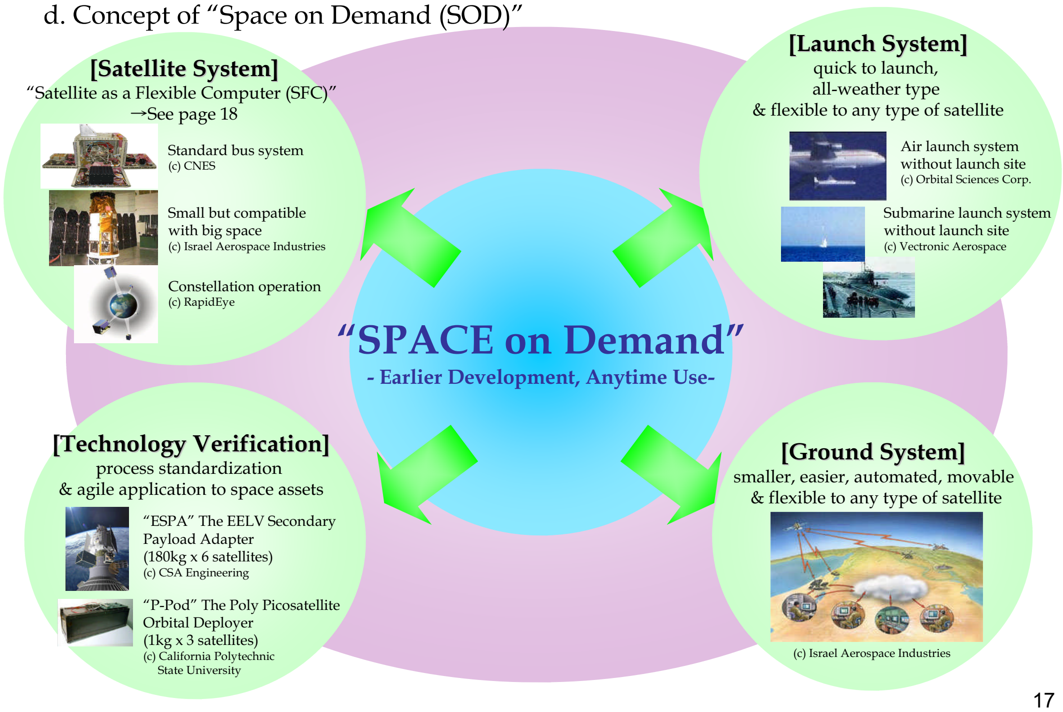
4. New Policy Concept "Space on Demand"

経済産業省 METI Ministry of Economy, Trade and Industry

d. Concept of "Space on Demand (SOD)"



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4. New Policy Concept "Space on Demand"

経済産業省 Ministry of Economy, Trade and Industry METI

e. Concept of "Satellite as a Flexible Computer (SFC)"

(a) Software given priority

(1) **Automated intelligent** system by maximum use of S/W & **improvability in orbit**

(2) **Inter-operable & compatible** with general systems (including personal computers)

(b) Standard bus & instruments design

(3) **Standard bus systems** flexible to various objects (pancromatic/ multi-spectral / hyper/ IR / SAR etc.)

(4) Standardization of **constellation** operations

(5) **Minimization** of satellite bus systems (mission / bus weight ratio)

(6) **Plug & Play** system through standardization of I/F in order to utilize **cutting-edge technologies**

(7) **Modularization** of components

(8) Flexible to **various orbits** (LEO, SSO, HEO & GEO)

(c) Interface for launch vehicle

(9) Flexible to **various launch vehicle**

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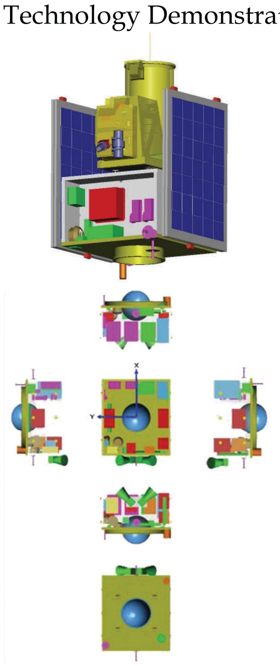
4. New Policy Concept "Space on Demand"

経済産業省 Ministry of Economy, Trade and Industry METI

f. Technology Demonstration



This demonstration includes the concepts of **"Space on Demand (SOD)"** & **"Satellite as a Flexible Computer (SFC)."**
Specifications as follows:

<Project overview>

Usage : Remote sensing (technology demonstration)
Development cost: about 25 million Dollar (3 billion Yen)
Development period: 08fy-10fy

<Standard bus>

Weight: 150-350kg
Life time: 3-4 years
Size: 1-1.2mx1-1.2mx1-1.2m
Orbit altitude: 400-500km

<Sensors>

Pancromatic sensor:
Spatial resolution < 1m (benchmark: 40-50cm)
Multispectral sensor:
Spatial resolution < 3m (benchmark: 1.5-2m)
5〜6bands

These specifications largely depend upon feasibility study we will start next month.

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Summary

経済産業省 Ministry of Economy, Trade and Industry METI

1. METI is obliged to maximize of space utilities for global consumers & enhance efficiency of industrial activities related to space.

2. From the view of ensuring low cost, short-term delivery & high tech METI has long highlighted the importance of application of COTS technologies to space crafts.

3. USERS & SERVIS projects provided us satellite standard bus system, COTS Database, COTS Parts Evaluation Guidelines, Equipment Design Guideline thanks to USEF (Institute for Unmanned Space Experiment Free-Flyer).

4. Now METI has launched the new project to "Space on Demand" in order to make our space systems more efficient and start COTS technology demonstration satellite project next year utilizing the outcome of previous projects.

Thank You For Your Attention!!

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The 20th Microelectronics Workshop

COTS Parts Evaluation in SERVIS Project

Hiroshi Kanai, Kazumori Hama, Masatsugu Akiyama
Institute for Unmanned Space Experiment Free Flyer (USEF)
Osamu Itoh
New Energy and Industrial Technology Development Organization (NEDO)

Agenda

- About USEF
- Purpose of SERVIS project
- Ground tests and their results
- Payloads of SERVIS satellites
- On-orbit verification test results of SERVIS-1
- Conclusion

1

About USEF

- USEF: Institute for Unmanned Space Experiment Free Flyer
- Established on May 16, 1986
- USEF is a non-profit organization endowed by 13 private companies and is managed under the direction of the Ministry of Economy, Trade and Industry (METI).
- Objectives:
  USEF was established to promote development of unmanned space experiment systems and their operational control systems as well as to conduct research and other activities as related the above-mentioned systems.

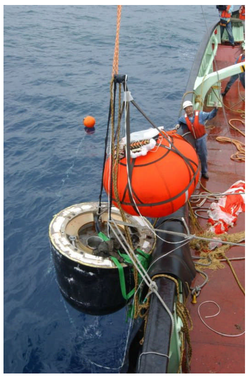
2

Satellites developed and launched by USEF/NEDO

Space Flyer Unit (SFU) launched in March, 1995 and retrieved in Jan. 1996

Experiment Reenrty Space System (EXPRESS) launched in Jan. 1995

Unmanned Space Experiment Recovery System (USERS) launched in Sep. 2002



Recovery of Reenty Module in May, 2003

3

SERVIS Project

- Space Environment Reliability Verification Integrated System
- To establish low cost spacecraft technology by utilizing commercial-off-the-shelf parts and technologies (COTS)
- To increase cost and technical competitiveness of the Japanese space industry
- Program duration: 1999 thru 2010
- Two verification flights: 2003, 2009 (Planned)

SERVIS Project is being developed by USEF under contract with METI – NEDO.

4

Why do we challenge on COTS?

Electrical Parts used for USERS SEM

Type	Quantity	Cost Breakdown
CPU, Memory, GA	250	87%
Digital IC	2,530	2%
Semiconductor	6,720	1%
Resister, Capacitor	14,600	2%
Solar Cell, Relay, etc.	13,800	8%
Total	37,900	100%

- Drastic parts procurement cost reduction can be achieved, if CPU, memory and GA could be replaced with inexpensive COTS.

5

Why do we challenge on COTS?

- Compared with MIL class, high reliable part applied equipment, COTS applied equipment have the following advantages.

➢ Higher performance, lighter and smaller equipment can be realized.

➢ Some functions realized on conventional electrical circuits could shift to software, resulting in lower cost.

➢ Some equipment units could be integrated into one unit, resulting in lower cost.

- To be concentrated on high performance COTS devices such as CPU, Gate Array, memory.

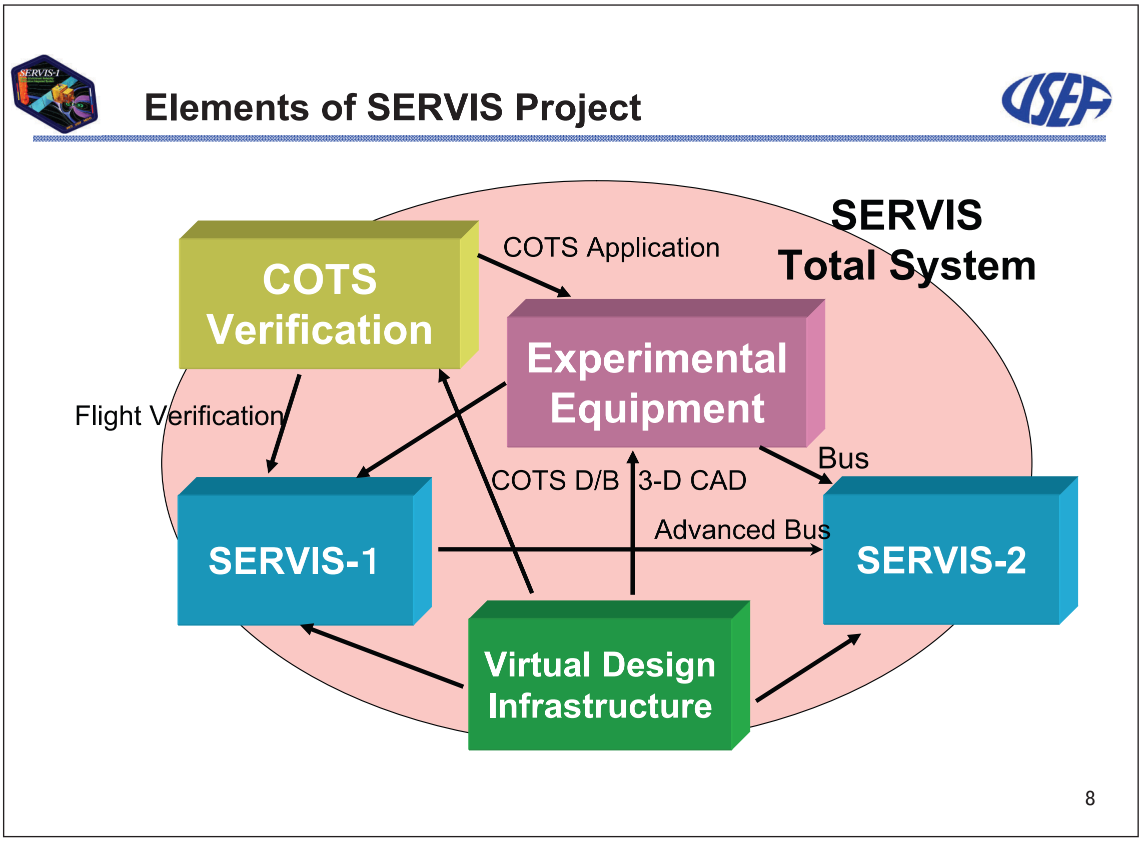
6

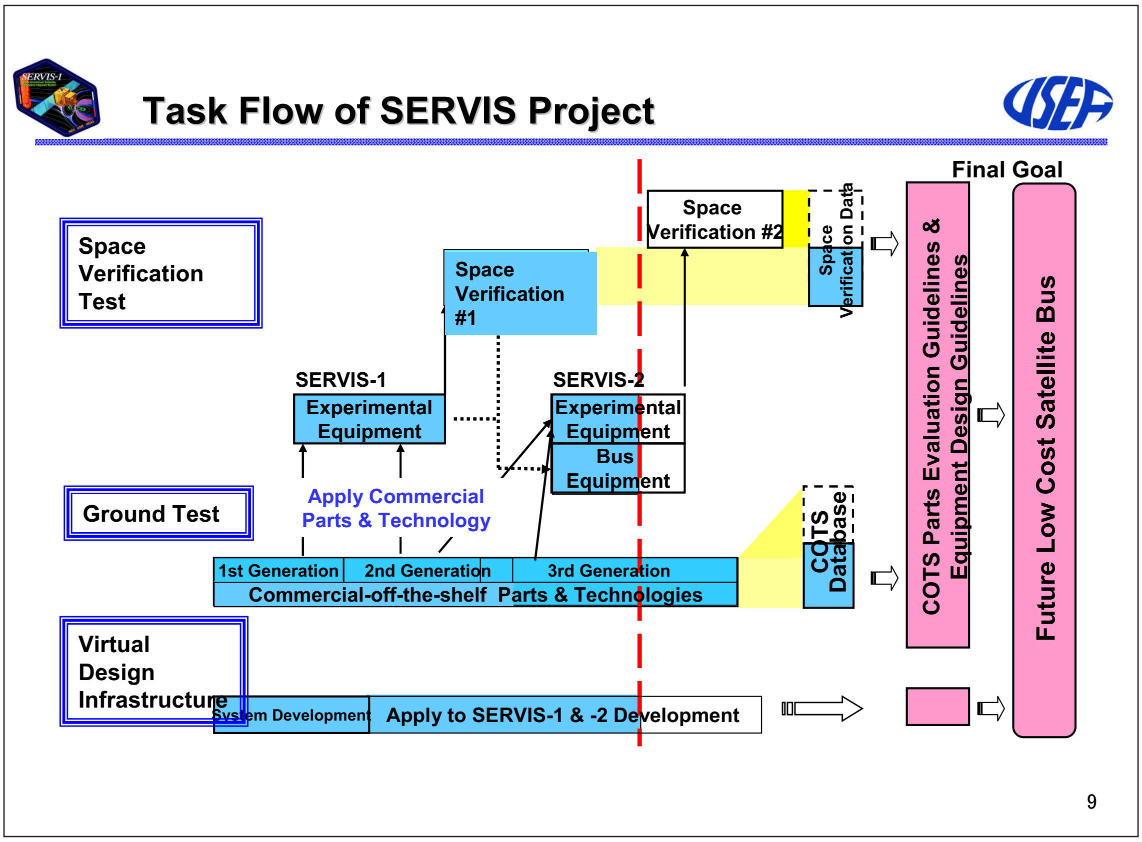
How to realize COTS application?

- Extensive COTS ground evaluation tests especially on radiation tolerance
- Confirmation by on-orbit verification
- Evaluation and correlation of the both results

- Output (Technical knowledge base)
  1) COTS Database
  2) COTS Parts Evaluation Guidelines
  3) Equipment Design Guidelines

7


SERVIS-1
Elements of SERVIS Project
USEF
SERVIS
Total System
COTS
Verification
COTS Application
Experimental
Equipment
Flight Verification
COTS D/B
3-D CAD
Bus
Advanced Bus
SERVIS-1
SERVIS-2
Virtual Design
Infrastructure
8


SERVIS-1
Task Flow of SERVIS Project
USEF
Final Goal
Space
Verification
Test
Space
Verification #2
Space
Verification Data
Space
Verification
#1
SERVIS-1
Experimental
Equipment
SERVIS-2
Experimental
Equipment
Bus
Equipment
Ground Test
Apply Commercial
Parts & Technology
1st Generation
2nd Generation
3rd Generation
Commercial-off-the-shelf Parts & Technologies
COTS
Database
COTS Parts Evaluation Guidelines &
Equipment Design Guidelines
Future Low Cost Satellite Bus
Virtual
Design
Infrastructure
System Development
Apply to SERVIS-1 & -2 Development
9

COTS Procurement and Ground Evaluation Test

- **Procurement**
  - One time procurement for several projects/satellites
  - No special quality control requirements

- **Ground Evaluation Tests**
  - Screening test: based on MIL-STD-883 test methods to all purchased parts
  - Radiation Test:
    Total ionizing dose test
    Heavy ion- and proton-induced single event tests
  - Quality Conformance Inspection:
    Sampling test based on MIL-STD-883 test methods

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Ground Evaluation Tested COTS

Part's Type	1999	2000	2001	2002	2003	2004	2005	2006	Total
CPU	5	3	4	1	0	0	0	0	13
DSP	1	0	1	0	0	0	0	0	2
SRAM	4	12	6	1	1	1	1	1	27
SOI-SRAM	3	1	4	0	2	0	0	0	10
DRAM	1	10	1	1	3	1	1	0	18
PROM	0	2	0	0	0	0	0	0	2
EEPROM	2	1	1	0	0	0	0	0	4
Flash Memory	0	0	3	0	1	0	0	0	4
Gate Array	3	0	7	1	2	0	0	0	13
Digital IC	3	0	19	5	0	0	0	0	27
Digital IC(SOI)	2	2	2	0	2	0	0	0	8
Analog IC	6	10	21	4	1	0	0	2	44
Optical	2	3	1	0	0	0	0	0	6
SOI	0	1	0	0	0	0	0	0	1
Others	5	5	11	1	1	0	2	0	25
Total	37	50	81	14	13	2	4	3	204

11

Summary of Ground Test Results

■About sixty percent of ground-tested COTS can be used for LEO (low earth orbit) satellites with the following conditions:

- Orbit: <1000 km
- Mission Duration: < 5 years
- Shield Thickness: > 5 mm(Al)
- Single Event Upset: acceptable
- Single Event Latch-up: not acceptable

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Ground Evaluation Test Results of COTS

ID	Sample	Specifications	Measured Radiation Tolerance			
			TID	SEU		SEL
				LETth	Saturated Cross Section	
			Gy(Si)	MeV/(mg/cm^2)	cm^2	MeV/(mg/cm^2)
11114	CPU	32bit, RISC, Vcc=5.0V, 28MHz	200	<2.9	>1.0E-6(d)	>61.8
21101	CPU	32bit, RISC, Vcc=3.3V, 100MHz	170	3.5	9.24E-3(d)	>60
11215	SRAM	4Mbit (256kword x 16bit), Vcc=3.3V	500	2	1.2E-7(b)	>61.8
21105	SRAM	4Mbit (256kword x 16bit), Vcc=3.3V	>361	2	3.39E-7(b)	>59.9
21307	SOI-SRAM	256kbit (32kword x 8bit), Vcc=1.5V	580	7.7	1.0E-8(b)	>82.4
11222	DRAM	256Mbit (16Mword x 4bit x 4bank), Vcc=3.3V	600	5	1.0E-7(b)	>61.8
11224	DRAM	256Mbit (16Mword x 4bit x 4bank), Vcc=3.3V	>500	<1.5	1.6E-6(b)	>63
61103	EE-PROM	64Mbit (8Mword x 8bit), Vcc=3.3V	850	82.8	1.0E-6(b)	11.4
11319	FPGA	SRAM type, Vcc=3.3V	500	<1.5	3.0E-6(d)	14.2

Note (b): per bit, (d): per device

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Payloads for SERVIS-1 and -2

- **Experimental Equipment**
  To obtain COTS data through equipment performance
- **Commercial Parts Test Unit (CPT)**
  To obtain COTS data as part level
- **Space Environment Monitoring System (EMSS)**
  To measure space radiation environments which COTS encounter

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Criteria for Selection of Experimental Equipment

- They should represent equipment for future low cost LEO satellites.
- They must be internationally competitive.
- Those equipment for which on orbit test is effective for their evaluation and verification.

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Experimental Equipment on SERVIS -1

No.	Equipment	Electrical Parts	Techno-logy	Electrical Part Type	Technology Name
1	VTS	1	1	Void sensor	Super Plastic Forming
2	INU	1	0	RF Device in GPS Receiver	-
3	PCDS	1	0	16bit CPU	-
4	APDM	0	1	-	Grease Lubricant
5	ATTC	11	1	16b D/A C, 12b A/D C, Receiver IF, Low Noise Amp., Low Noise Amp./Mixer, Transmit/Receive Switch, Up Comverter, Modulator, Transceiver, Power Amp. Driver Amp., Driver Amp.	Surface Mount Technology
6	OBC	6	1	CPU, SDRAM, FPGA, Dig_IC×2, SRAM	Multi-chip Module
7	SIS	4	1	CPU, EEPROM, CCD, SDRAM	Surface Mount Technology
8	LIB	0	2	-	Lithium-ion Battery Cell, Power Hybrid IC
9	FOIRU	5	0	Super Luminescent Diode, Avalanche Photo Ddiode Integrated Optic Modulator, Optical Fiber, Fiber-Optic Gyro	-
10	CPT	11	0	SRAM×2, SDRAM×2, Flash Memory, FPGA×2, SOI-SRAM×2, EEPROM, LVDS Driver	-
Total		40	7		

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Experimental Equipment on SERVIS-2

No.	Equipment	Electrical Parts	Techno-logy	Electrical Part Type	Technology Name
1	LIBA	7	1	32bit CPU, Multiplexer, Photo-Coupler, Relay Driver, MOS-FET, OP Amp., Hole Sensor	Lithiumi-ion Battery Cell
2	ADMS	17	0	32bit CPU, Flash Memory SRAM, FPGA, FET, Digital ICx6, Analog ICx4, Transistorx2	-
3	CRAFT	4	0	64bit MPU(P-QFP), 64bit MPU(BGA), SRAM, SDRAM	-
4	PPRTU	9	0	IEEE-1394 I/F LS, PLL LSI, LVDS Line Driver, LVDS Line Receiver, PCI I/F Device, Dual Port SRAM, High Speed FIFO, EDAC, Buffer IC	-
5	HPDC	7	2	LVDS Line Driver, LVDS Line Receiver, LVDS Line Driver/Receiver, Line Receiver, 16bit Level Shifting Tranceiver, SDRAM, Image Comp Chip	Multi-Chip Module, SOI Technology
6	APE	4	2	OP Amp., FIFO, FPGA, SDRAM	GPS Receiver, Mounting Technology
7	ASM	7	1	32bit CPU, FPGA, Driverx2, OP Amp., EEPROM, SDRAM	Mounting Technology
8	MBW	1	1	Power MOSFET	Magnetic Bearing
9	MEMS	1	1	RF-MEMS Switch	MEMS Manufacturing Process
10	CPT	9	0	SRAMx2, SDRAMx2, Flash Memory, FPGAx2, SOI-SRAMx2	-
Total		66	8		

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COTS evaluated by CPT

	SERVIS-1	SERVIS-2
SRAM	1Mbit, 4Mbit	4Mbit, 8Mbit
DRAM	128Mbit, 256Mbit	256Mbit, 512Mbit
SOI SRAM	256kbit (0.35 micron m rule)	128kbit (0.18 micron m rule)
Flash Memory	NOR type 32Mbit	NOR type 128Mbit
FPGA	SRAM type, EEPROM type	SRAM type, EEPROM type

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External View of SERVIS-1

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Summary of SERVIS-1 Satellite

- Launch Date: October 30, 2003
- Launch Vehicle/Site: ROCKOT/Plesetsk Cosmodrome (Russia)
- Orbit: altitude=1000km, Inclination=99.5deg (Sun Synchronous)
- Dimension in Orbit: 2.5m(H) X 10.2m(L)
- Launch Mass: 840kg
- Operation Period: 2 years
- Electrical Power Generation: Not less than 1300 watts
- Communication: Unified S-Band and High Rate S-band
- Operation Center: USEF Space Operations Center (Tokyo)

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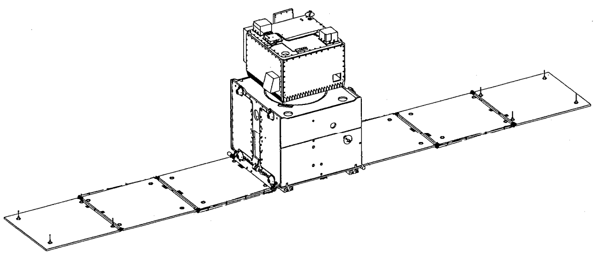
Summary of SERVIS-2 Satellite

- Launch Year: 2009 JFY (Planned)
- Launch Vehicle: ROCKOT
- Orbit: Altitude=1200km, Inclination=100.4deg (SSO)
- Launch Mass: Less than 900 kg
- Operation Period: 1 year
- ATTC, SIS and LIB based bus equipment



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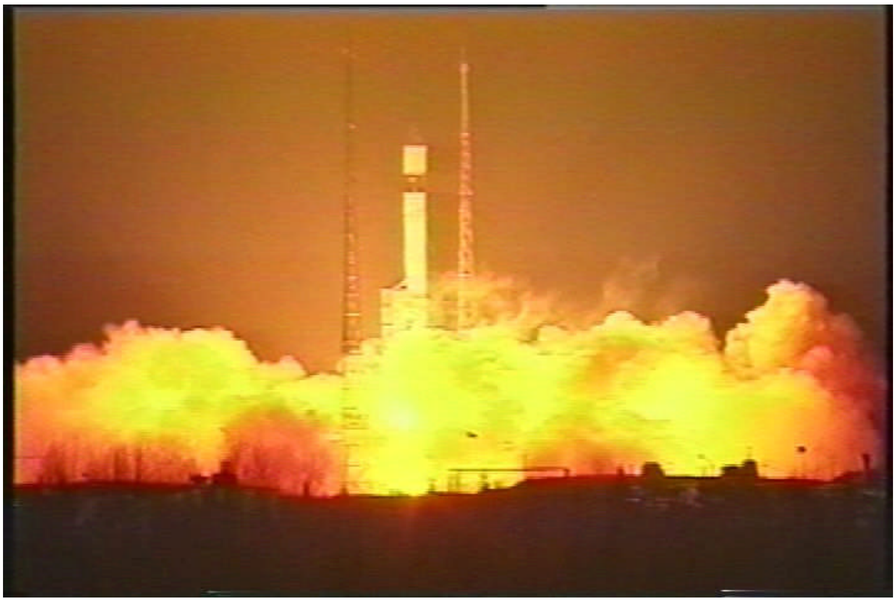
Launch of SERVIS-1

Launched at 16:43:41(LMT(*)), on October 30, 2003　(*): UT+3H



Space Experiment Results of SERVIS-1

■**SERVIS-1 Bus**

- ●SERVIS-1 continues flawless operation on orbit.

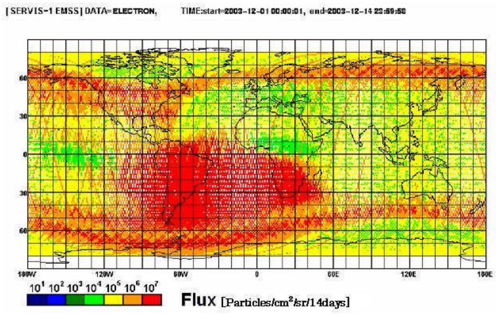
■**COTS Parts**

- ●Single Event Upsets occur within the predicted frequency.
- ●Permanent damage such as Single Event Latch-up or Burn-out has not been observed.

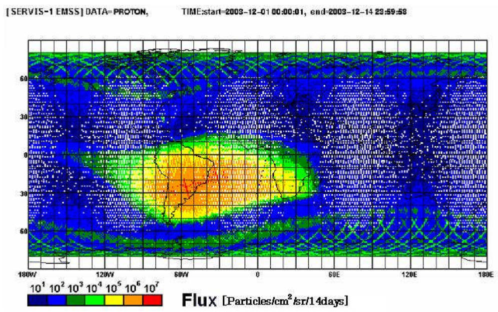
■**Experimental Equipment**

- ●VTS experiment was successfully finished in Dec. 2003.
- ●The other experimental equipment had been working well.
- ●No serious malfunction caused by COTS has observed.

Electron and Proton Flux on World Map



Electron Flux



Proton Flux

Ground and On-orbit TID Tolerance

CPT		Ground Test Result Gy (Si)	Result on Orbit Gy (Si)
SRAM 1A	1Mb SRAM	180	163
SRAM 1B			120
SRAM 2A	4Mb SRAM	400	342
SRAM 2B			382
DRAM 1A	128Mb DRAM	600	>951
DRAM 1B			>951
DRAM 2A	256Mb DRAM	600	>951
DRAM 2B			>951

Predicted and Measured Single Event Upset

Equipment	Part ID	SEU (times)		
		Predicted values		Measured values on orbit
		by heavy ion irradiation test	by Proton irradiation test	
OBC	32 bit CPU	3.9 / day	-	0.16 / day
	64M SDRAM	17 / day	-	0.02 / day
	4M SRAM	17 / day	-	3.4 / day
SIS	32bit CPU	0.23 / day	-	0.073 / day
	1M EEPROM	0 / day	-	0 / day
	256M SDRAM	4.5 / day	-	0.3 / day
ATTC	16bit DAC	0.8 / day	-	0 / day
	16bit ADC	1.0 / day	-	0 / day
PCDS	16bit CPU	-	2.0 / year	1.1 / year
CPT	1M SRAM	1.0 / day	2.8 / day	1.2 - 2.2 / day
	4M SRAM	3.4 / day	6.6 / day	2.2 - 8.3 / day
	128M SDRAM	2.6 / day	0.2 / day	0.33 - 0.38 / day
	256M SDRAM	3.6 / day	0.5 / day	0.5 - 0.9 / day

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COTS Database

- Contains ground test results.
- Has two tier constructions:
  - limited information open to the public,
  - detailed data for internal use

COTS Database

No.	ID number	Part's Type	Function	Radiation Tolerance								Temparature Range (Catalogue base)		Environment Test					
				TID Tolerance		SEU Tolerance													
				Gamma-ray TIO	Proton TID	Heavy-Ion SEU/SET		Proton SEU/SET		Heavy-Ion SEL/SEB		Operating Range	Storage Range	Stabilization Bake	High temperature Operating Life Test	Temperature & Humidity Bias Test	Pressure Cooker Test	Temperature Cycling	Temperature shock
				Gy(Si)		Threshold LET	Saturated Cross Section	Threshold Energy	Saturation Cross Section		Saturated Cross Section								
						MeV/(mg/cm^2)	cm^2	MeV	cm^2	MeV/(mg/cm2)	cm^2	℃	℃	Rejected/Tested					
(CPU)																			
1	11101	CPU	32bit(Internal Bus:128bit)、DRAM:2MB	>200	-	<1.44	>2.25E-03(d)	-	-	59.8	Function error	0 ~ +70	-60 ~ +150	0/22	0/22	0/22	0/22	0/22	-
2	11112	CPU	32bit	150	-	<1.5	>2.0E-06(d)	-	-	5.5	>1.0E-06(d)	-20 ~ +75	-55 ~ +125	0/11	0/11	0/11	0/11	0/11	0/11
3	11113	CPU	32bit with FPU	200	-	<1.5	>4.0E-06(d)	-	-	5.5	>1.0E-06(d)	-20 ~ +75	-55 ~ +125	0/11	0/11	0/11	0/11	0/11	0/11
4	11114	CPU	32bit	200	-	<2.9	>1.0E-06(d)	-	-	>61.8	<1.0E-06(d)	-40 ~ +110	-65 ~ +150	0/11	0/11	0/11	0/11	0/11	0/11
5	11225	CPU	32bit	150	<240	~2	~1.0E-06(b)	<20	>3E-13(b)	5.5	4.9E-06(d)	-40 ~ +110	-65 ~ +150	0/11	0/11	0/11	0/11	0/11	0/11
6	11401	CPU	32bit	200	<400	1.5	5E-08(b)	<9.7	1E-013(b)	1.5	4.9E-07(d)	-40 ~ +85	-65 ~ +150	0/45	0/32	0/22	0/22	0/22	0/22
7	21101	CPU	32bit, RISC, 100MHz	170	-	3.5	9.24E-03(d)	-	-	>60	<1.0E-05(d)	-40 ~ +110	-55 ~ +150	0/5	0/7	-	-	0/7	-
8	41315	CPU	64bit	>300	-	3	2.0E-03(d)	-	-	19.8	9.8E-05(d)	-30 ~ +85	-65 ~ +150	-	0/5	-	-	0/4	-
9	41320	CPU	64bit	>300	-	3	1.7E-07(b)	-	-	14	6.6E-07(d)	0 ~ +70	-65 ~ +150	-	0/5	-	-	0/4	-
10	51201	CPU	MPU	<200	307	4.3	1.0E-05(b)	0.12	1.5E-13(b)	26.2	4.56E-04(d)	-40 ~ +85	-55 ~ +125	0/22	0/22	0/22	0/22	0/22	0/22
11	51301	CPU	16bit CPU, Flash Memory :256kB, RAM : 8kB	123	-	0.64	7.9E-08(b)	0.5	4.0E-14(b)	1.85	6.7E-03(d)	-40 ~ +85	-55 ~ +125	0/45	0/76	0/76	0/22	0/45	0/22
12	51308	CPU	32bit,40MHz,3.3V, Flash Memory : 512kB, RAM	200	-	2.9	2.0E-04(d)	16.3	1.59E-16(b)	5	6.80E-04(d)	-40 ~ +85	-55 ~ +125	0/45	0/76	0/45	0/22	0/45	0/15
13	61204	CPU	16bit	300	-	7.5	7.0E-03(d)	-	-	26.2	>2.5E-05(d)	-40 ~ +85	-55 ~ +125	0/3	0/12	0/6	0/5	0/6	-
14	U1001	CPU	32bit	>300	-	9	1.0E-04(d)	-	-	34	Latch-up	-	-	-	-	-	-	-	-

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Guidelines

■COTS Parts Evaluation Guideline

✓Specifies basic requirement for COTS for space application.

✓Has two appendices:

1) specify detailed ground test items & their conditions
2) explanations on COTS general property & advantages

✓Contents

1. Scope
2. Applicable Documents
3. Basic Concept
4. COTS Parts Selection Criteria
   - 4.1 Definition of COTS Parts
   - 4.2 Environment Test Condition
   - 4.3 Selection Criteria
5. Evaluation Test
   - 5.1 Screening Test &its Condition
   - 5.2 Quality Conformance Inspection & its Condition
   - 5.3 Radiation Tolerance Test
     - 5.3.1 TID Test Method
     - 5.3.2 Single Event Effect Test Method
     - 5.3.3 Other Radiation Tests
6. Reliability Consideration

■Equipment Design Guideline

✓Indicates items to be considered for COTS applied equipment design.

✓Has an appendage which shows how COTS parts were applied in 9 experimental equipment.

✓Contents

1. Scope
2. Applicable Documents
3. Definitions
4. Design Guidelines
   - 4.1 General Requirements
   - 4.2 Overall Equipment Design
   - 4.3 Electrical Design
   - 4.4 Mechanical Design
   - 4.5 Thermal design
   - 4.6 EMC Design
   - 4.7 Radiation Tolerance Design
   - 4.8 Interface Design
   - 4.9 Reliability Design
   - 4.10 Safety Design
   - 4.11 Parts Mounting Design
   - 4.12 Parts and Material Selection

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Conclusion

- 204 COTS have been ground tested, and the test results have been accumulated in the COTS database.
- Experimental equipment with COTS onboard of SERVIS-1 have performed satisfactorily and it has been demonstrated that COTS can be used for space.
- First editions of Parts Evaluation Guidelines and Equipment Design Guidelines have been opened, waiting to be brushed up by the coming SERVIS-2 space verification results.
- Through the program, the advanced low cost LEO bus is being developed.

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Hybrid Microcircuit Inherent Reliability for Space Applications

Jeffrey H Sokol, PhD, CFA

Presented at the MEWS 2007
October 29, 2007

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Outline

- Abstract
- Introduction
- PWB Assembly Comparison to a Hybrid
- Characteristics of a PWB Assembly
- Characteristics of a Hybrid
- Types of Hybrid Problems Encountered
- Suggestions for Spec Improvement
- Summary

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Abstract

- Space programs utilize hybrid microcircuits over other forms of packaging for savings of space and weight
- Hybrid microcircuits built for space applications utilizing the requirements in MIL-PRF-38534 have the potential for inherent reliability shortfalls that typically are not associated with PWB assemblies.
- This presentation will discuss these potential shortfalls and provide suggestions for improvement of the aforementioned military specification.

Introduction

- What is a hybrid?
  - A hybrid is nothing more than a miniaturized version of a larger Printed Wiring Board (PWB) assembly intended to save board space and reduce weight.
  - In some cases, typically RF applications, the hybrid version of the design has better performance than its full size PWB version.

Introduction (Cont'd)

- MIL-PRF-38534, Rev F is the military specification governing the design, construction, qualification, testing, and procurement of hybrid microcircuits for military and space applications.
- Class H hybrids are intended for military terrestrial applications.
    - However they have been used in some space applications with up-screening.
        - Up-screening has usually been limited at a minimum to inclusion of PIND to more rigorous testing approaching Class K requirements.

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Introduction (Cont'd)

- MIL-PRF-38534 (Cont'd)
    - Class K hybrids are intended for space applications.
        - Standard supplier hybrid offerings are defined by a Standard Microcircuit Drawing (SMD)
        - Custom hybrids are procured to a Source Control Drawing (SCD)
        - Some custom hybrids are not entirely compliant to the 38534 requirements for Class K.
            - Class G hybrids are meant to deal with the above situation and defines the non-compliances to Class K

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PWB Assembly Comparison to a Hybrid

- Both utilize a type of circuit card
  - PWB Assemblies use a PWB
  - Hybrids use a substrate that typically contain various types of elements including integral resistors and capacitors
- Both use Microcircuits & Semiconductors
  - PWB Assemblies use packaged devices
  - Hybrids use dice elements unpackaged
- Both use passive devices
  - PWB Assemblies use packaged and unpackaged devices
  - Hybrids use packaged devices or unpackaged dice
    - Oscillators typically use unpackaged crystals

Characteristics of a PWB Assembly

- Microcircuits should meet the appropriate requirements of MIL-PRF-38535 for the quality level specified - Class Q for avionics and Class V for space.
  - Should be screened and periodically qualified to the requirements set forth in MIL-STD-883 methods 5004 and 5005.
    - Parts are either procured to a QML Standard Microcircuit Drawing (SMD) or an SCD compliant to the above requirements.

Characteristics of a PWB Assembly (Cont'd)

- Semiconductors should meet the requirements for the appropriate quality level as set forth in MIL-PRF-19500.
  - Generally, JANTXV for avionics and JANS for space has been used.
  - Procured to QPL 19500 slash sheet part or upgraded lower quality level device.
  - Or, procured as a custom device to a SCD.
- Passive Devices (resistors, capacitors, inductors/transformers, etc.) should meet the requirements of their associated military specification (e.g. MIL-PRF-55342, 123, 55365, etc.) for ER level R for avionics and S or better for space.

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Characteristics of a Hybrid

- Microcircuit dice from the appropriate qualified QML quality level lots should be the first choice.
  - Typically this is not the case.
    - COTS dice are being regularly used.
  - Screening is restricted to visual and DC electrical tests at 25° C only.
  - Sample (***ONLY*** 10 pieces) qualification is performed
    - Class H hybrid - restricted to internal visual, tri-temp electrical tests and wire bond testing.
    - Class K hybrid - temperature cycling, mechanical shock/constant acceleration, burn-in, 1000 hour life test at 125° C, and SEM in addition to internal visual, tri-temp electrical tests and wire bond testing.

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Characteristics of a Hybrid (Cont'd)

- Semiconductor QPL qualified dice should be the first choice - HC for Class H and KC for Class K
  - Generally this is not the case.
    - Again, COTS are being used.
  - Screening and sample qualification are the same as that being used for microcircuit dice.
- QPL passive devices (resistors, capacitors, inductors/transformers, etc.) should be the first choice.
  - Once again, this is not typically being done.
    - COTS chip passive devices are being used.
  - 100% screening and sample qualification are the same as that being used for microcircuit dice.
  - Voltage/Current/Power conditioning performed in lieu of burn-in during qualification test.
    - However, remainder of flight parts are not required to have this conditioning performed.

Types of Hybrid Problems Encountered

- Design Issues
  - No margin
  - Does not meet performance across full temperature or signal conditions
- Derating issues
  - Inadequate or no derating
- Manufacturing Issues
  - Poor workmanship
  - Bonding
  - Die Attach
- Test Issues
  - Inadequate tests to validate all performance characteristics
- Qualifications Issues
  - Failures
  - Limited tests or conditions

Suggestions for Spec Improvement

- Improved element evaluation regimen needs to be implemented
  - Qualification sample sizes need to be consistent with those used for the discrete device versions
    - Non QML microcircuits should be using 45 pieces instead of 10
    - Non QPL semiconductors should be using at least 45 pieces instead of 10
    - Non QPL passives should be using at least 45 pieces instead of 10

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Suggestions for Spec Improvement (Cont'd)

- Testing needs to be appropriate for the various element technologies
  - Semiconductor test flow should be the same as what is required in MIL-PRF-19500, Appendix G, instead of using a microcircuit test flow.
  - Passive devices should be tested to the requirements in the appropriate military specification for that technology
    - Chip capacitors should use MIL-PRF-123
    - Tantalum capacitors should use MIL-PRF-55365
    - Chip resistors should use MIL-PRF-55342
    - Magnetics should use MIL-PRF-981

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Suggestions for Spec Improvement (Cont'd)

- New Technology insertion requirements need to be added to better understand the failure mechanisms of devices, materials and processes
  - Characterization needs to be performed
  - Appropriate screening tests need to be developed to mitigate potential failure mechanisms detected
  - Appropriate qualification tests need to be defined or developed based on failure mechanisms detected
  - COTS should be treated as new technology

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Suggestions for Spec Improvement (Cont'd)

- Additional validation of second and third party subcontractors that perform design, manufacturing, test or other functions must be evaluated to ensure the quality and reliability integrity of the overall hybrid
- Additional manufacturing reviews need to be included to ensure the capabilities to build the hybrid can be achieved
- Testing/re-qualification when different manufacturer die elements are utilized

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Summary

- Presented the technical aspects of avionics and space hybrids governed by MIL-PRF-38534 and the comparison to a PWB.
- Identified some of the issues and concerns experienced with hybrids.
- Several suggestions for improvement to the mil spec have been outlined.

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MINISTÈRE DE LA DÉFENSE

EXPERIMENTATION OF THE NEW RELIABILITY PREDICTION METHOD FIDES

Franck DAVENEL, Philippe RICHIN, Christian MOREAU

DÉLÉGATION GÉNÉRALE POUR L'ARMEMENT

Summary of the presentation

1- Context

2- FIDES methodology
- Reliability assessment
- Reliability engineering

3- Experimentations

4- Deployment

5- Conclusion

1 - Context

- Reliability is a contractual requirement for evaluation and control of:
  - Operational availability
  - Exploitation costs

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1 - Context

- Existing predictive reliability methods are inadequate
  - MIL-HDBK-217 is widely obsolete
    - Not updated since 1991 / 1995,
    - Not adapted for civil application and pessimistic for civil components,…
  - IEC 62380 TR Ed.1 (RDF 2003) or PRISM® / 217+® don't propose complete answers
    - Not adapted for complex mission profile,
    - Not adapted for rugged environment (humidity, vibration,…,),
    - Unable to sort by COTS manufacturers,
    - …

military equipment	MIL HDBK 217F (Pi Q=10)	MIL HDBK 217F with correction	PRISM (217plus)	Field return
MTBF (in hours)	**3063**	**19036**	**59673**	**169895**

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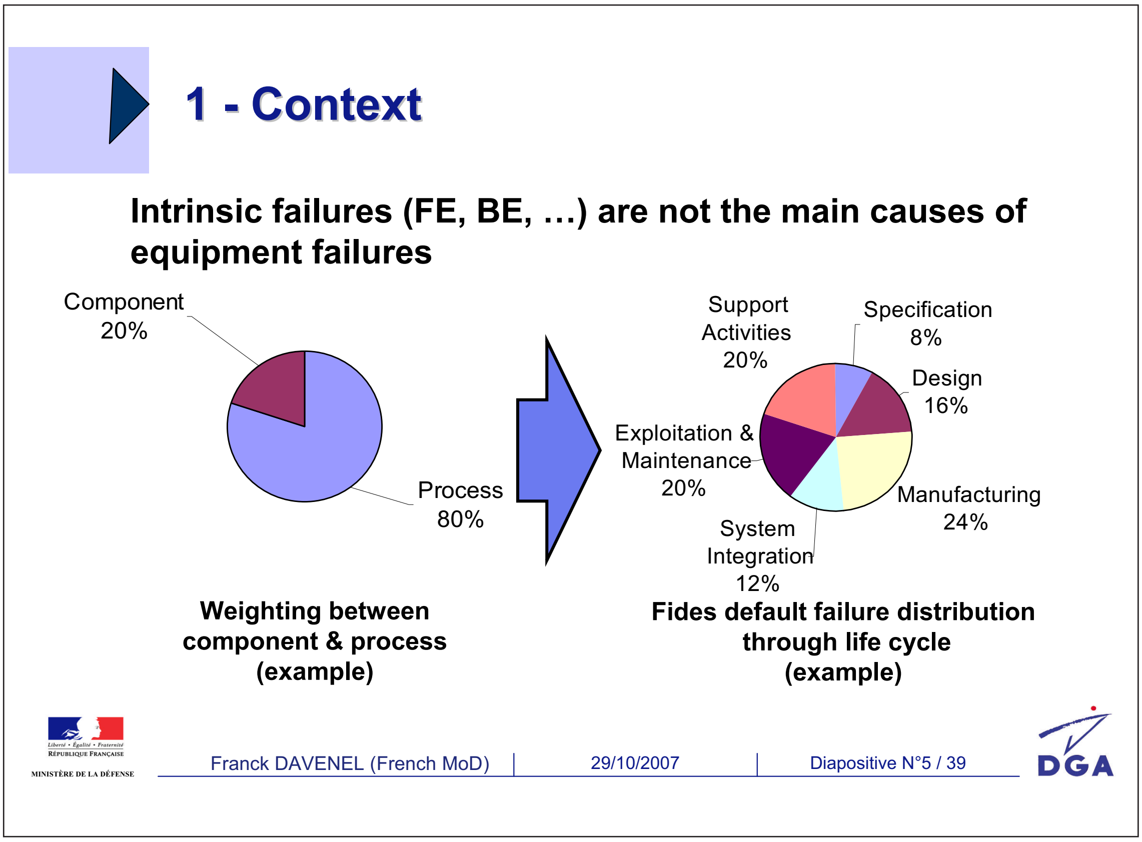
1 - Context
Intrinsic failures (FE, BE, …) are not the main causes of equipment failures
Component 20%
Process 80%
Support Activities 20%
Specification 8%
Design 16%
Exploitation & Maintenance 20%
Manufacturing 24%
System Integration 12%
Weighting between component & process (example)
Fides default failure distribution through life cycle (example)
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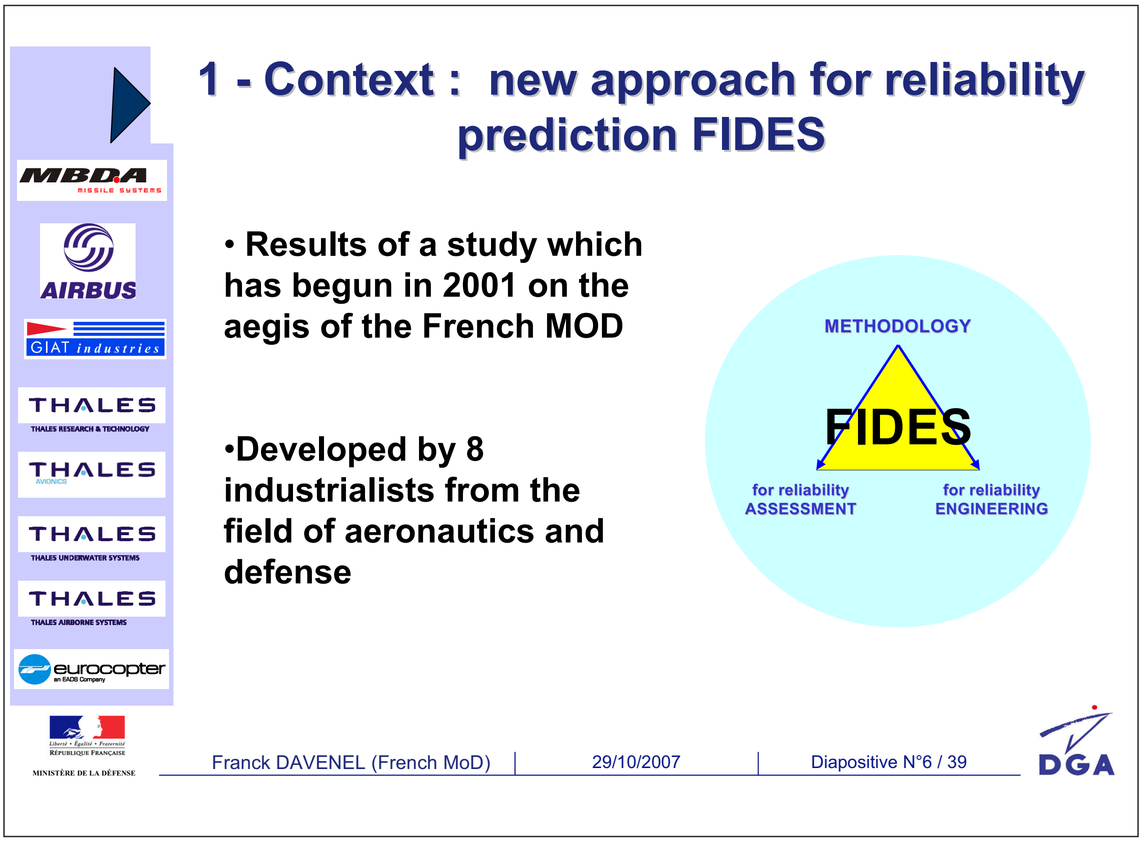
Franck DAVENEL (French MoD)
29/10/2007
Diapositive N°5 / 39
DGA


1 - Context : new approach for reliability prediction FIDES
MBDA
MISSILE SYSTEMS
AIRBUS
GIAT industries
THALES
THALES RESEARCH & TECHNOLOGY
THALES
AVIONICS
THALES
THALES UNDERWATER SYSTEMS
THALES
THALES AIRBORNE SYSTEMS
eurocopter
an EADS Company
• Results of a study which has begun in 2001 on the aegis of the French MOD
•Developed by 8 industrialists from the field of aeronautics and defense
METHODOLOGY
FIDES
for reliability ASSESSMENT
for reliability ENGINEERING
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1 - Context : what is FIDES

- FIDES is a new reliability methodology for electronic systems using COTS,
- The FIDES Guide 2004 issue A "Reliability Methodology for Electronic Systems" was published in 2004, and is now the standard UTE C-80811 since 2005 (in english & french),

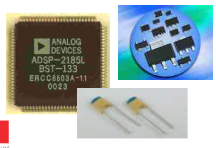
1 - Context : what is FIDES

- This Guide is an answer to two strong needs :
  - To have realistic reliability prediction during the development of an electronic product
  - To provide engineering process and tools to assess equipment system reliability

1 - Context : FIDES for what

- FIDES proposes a new reliability methodology for systems using COTS
  - As accurate as possible,
  - Useful for building and evaluating the reliability of systems,
  - Usable for many items , including COTS families,

Parts



Boards

Sub-assemblies

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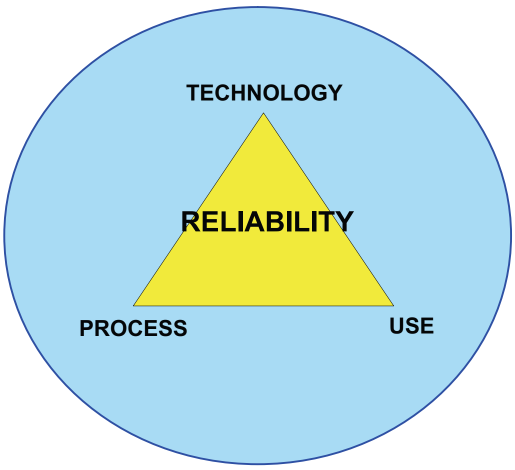
2- The methodology



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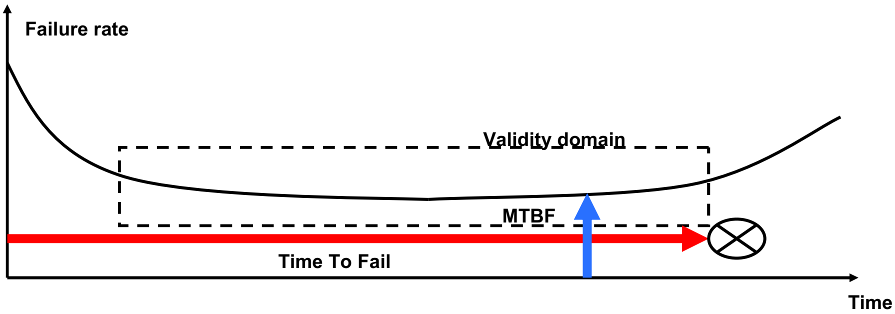
2- The methodology: failure rates

Complementarities

- Failure Rate (MTBF): reliability approach
- Time to fail (TTF): development engineers approach



2- The methodology: basic model

$$\lambda = \lambda_{Physical} \cdot \pi_{Part\_manufacturing} \cdot \pi_{Process} \cdot \pi_{Induced}$$

Where,

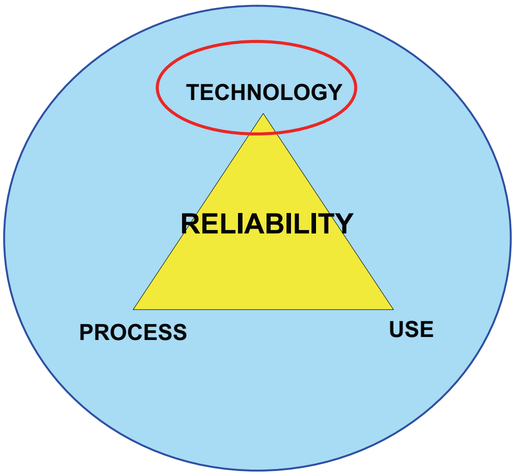
$\lambda_{\textbf{Physical}}$: Physical contribution : tables + used constraints

$\pi_{\textbf{Part\_manufacturing}}$: Quality and technical control of COTS manufacturing

$\pi_{\textbf{Process}}$: Quality and technical control of the development, manufacturing and maintenance process for products containing COTS

$\pi_{\textbf{Induced}}$: Induced factors (overstress) i.e. effects of accidental damage according to type of application, COTS sensitivity factor, location and robustness control => **questionnaire**

2- The methodology:Technology



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2- The methodology: physical contributors

$$\lambda_{Physical} = \left[\sum_{Physical\_contributions} \left(\lambda_0 \cdot \Pi_{acceleration} \right) \right]$$

λ_0 **Basic failure rate for each part type e.g. resistors, capacitors, inductors, switches, optoelectronics, I.C. and discrete semiconductors (die & package)** => table

$\Pi_{acceleration}$ **Acceleration factor (sensitivity to rated physical contributors e.g. electrical, thermal cycling, humidity, mechanical and chemical constraints) =>** mission profile

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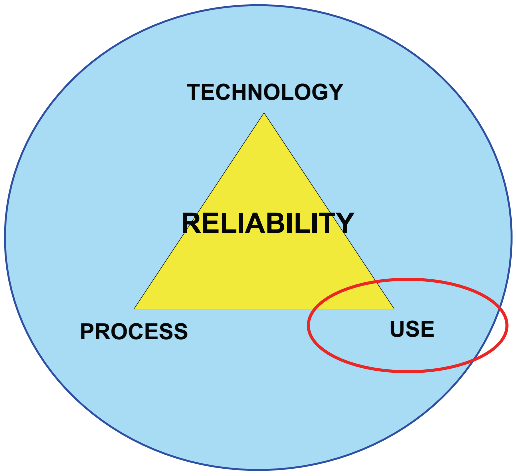
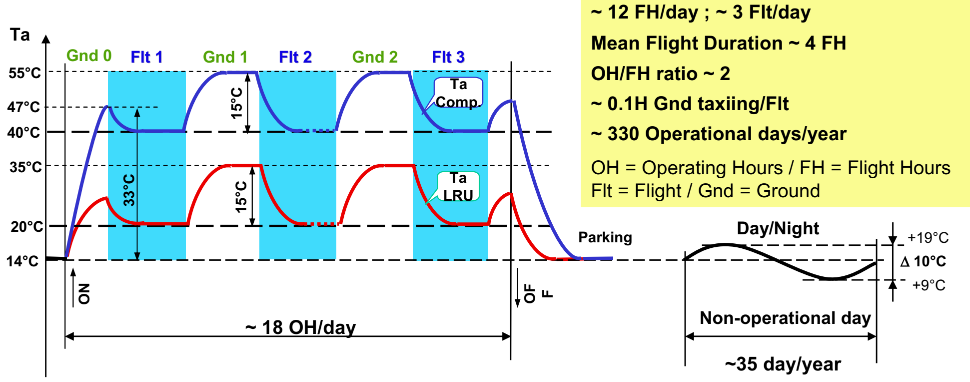
2- The methodology: USE



2-The methodology: mission profile

Middle Range, Civilian Aircraft Profile



~ 12 FH/day ; ~ 3 Flt/day
Mean Flight Duration ~ 4 FH
OH/FH ratio ~ 2
~ 0.1H Gnd taxiing/Flt
~ 330 Operational days/year
OH = Operating Hours / FH = Flight Hours
Flt = Flight / Gnd = Ground

1st step: decomposition of the mission profile in successive phases

2nd step: Inventory of the physical constraints associated to each of the phases

2-The methodology: Middle Range, Civilian Aircraft Profile

Medium//long-range civil aeronautics profile of use, computer in the bay

Constraint		Thermal and Humidity			Thermal cycling				Mechanical
Phase name	Calendar time (hours)	On/Off	Ambient temperature (°C)	Rate of humidity (%)	ΔT (°C)	Number of cycles (/year)	Cycle duration (hours)	Maximum temperature during cycling (°C)	Random vibrations (Grms)
Ground-operating-1	797	On	47	30	33	330	2	47	-
Ground-operating-2	1193	On	55	30	15	647	1.5	55	-
Ground-taxiing	84	On	47	5	-	-	-	-	5
Flight-operating	4083	On	40	5	-	-	-	-	0.6
Ground-dormant	2603	Off	14	70	10	108	24	19	-

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2-The methodology: induced factor

- What is an accidental overstress?
  - An accidental overstress is an event which is out a normal usage of the system (EOS, MOS, TOS).
- Criteria to appreciate the severity in term of exposure to overstress :

» Sensitivity of the COTS (technology, …)
» Policy of overstress integration in product development
» operating environment of the application (example MOS are more important in mobile than fixed application)
» Position of the item in the equipment or system

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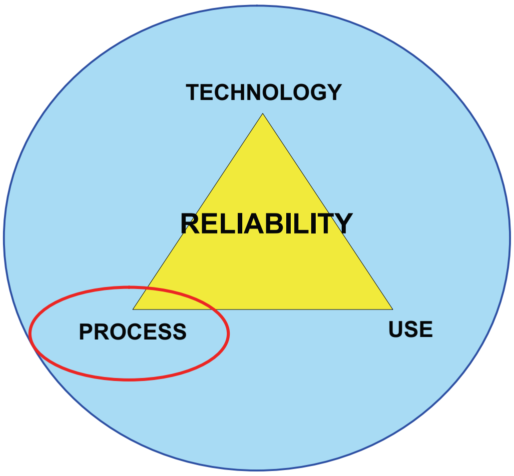
2- The methodology: process factor



2- The methodology: process factor

Building reliability:

200 recommendations related to activities for the whole life cycle,

- Specification,
- Design,
- Manufacturing,
- System Integration,
- Maintenance,
- Support activities (Quality and Human Resources)

This engineering allows:

- Calculation of process factor : $\pi_{process}$ to assess global reliability,
- Identification of life cycle activities where reliability needs improvement.

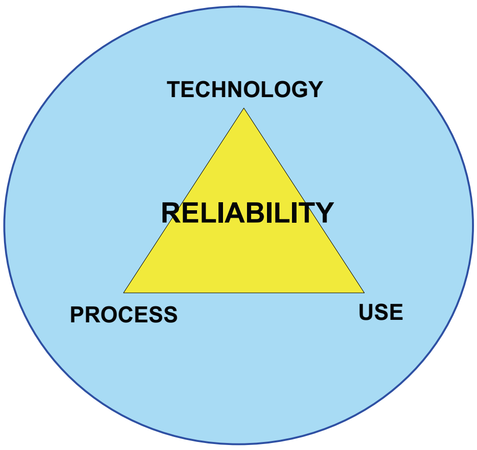
=> audit checklist

2- The methodology: audit checklist

Example of recommendation with weighting

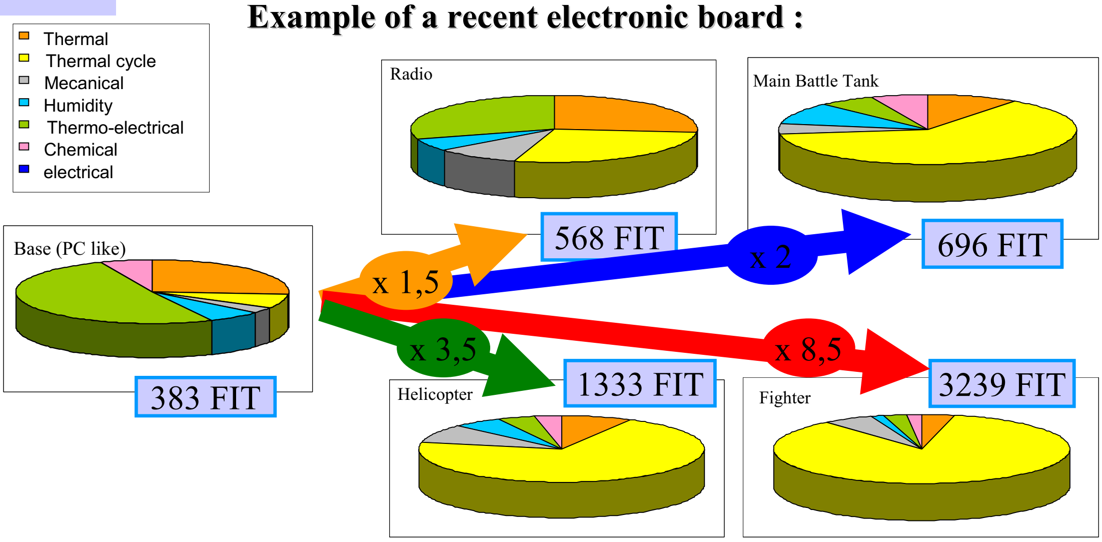
Life cycle	Audit question	Recommendation	Non applicable question	Weight recom	Application level			
					N1	N2	N3	N
					0	1	2	
Specification	Are reliability requirements assigned to subassemblies? Which method of allocation was used?	Assign reliability requirements to sub-assemblies		10,4				
	Is there a description and a characterization of the environment in which the system is going to be stored, transported, used and maintained?	Fully describe the environment in which the system is going to be used and maintained.		12,4				
	What is considered as a failed system?	Define the failed system		10,3				
	Have we defined the use profile of the system for which the reliability performances are expected?	Define the use profile of the system for which the reliability performances are expected.		9,9				
Design	What is the system reliability process implemented by the company?	Describe the system reliability process implemented by the company		7,5				

3- Experimentation



3- Experimentation : Mission profile influence

Example of a recent electronic board :



Generally, Pi E ARW >AUF in MIL 217

3- Experimentation : mission profile influence

- **Take into account soft and harsh mission profiles**
- **richness of the detailed mission profile description with the real stresses and not fixed values like MIL HDBK 217 (π_E)**
- **Be careful, need to know with precision all the parameters (environmental, utilization,…) of the mission profile**

3- Experimentation : RADIO equipment reliability assessment

- About 6000 electronic components (COTS) in a equipment
- 20000 equipments deployed in French Army
- Since 1994 more than 500 milliards component.hours
- Between 500 and 800 field return components per year for 12 years

military radio equipment		Failure rate (fit or 10-9/h)							RATIOs		
	components quantity	MIL HDBK 217F (Pi Q=10) (*)	UTE C 80810 (RDF2000)	PRISM (217plus)	Field return	FIDES intrinsic	FIDES total Pi $_{PM}$ = 1,42 Pi proc = 2,5	FIDES total (défault values : Pi $_{PM}$ = 1,7 Pi proc = 4)	MIL / Field return	PRISM / field rturn	FIDES total / field return
	5942	**326433**	**9782**	**16758**	**5886**	**1378**	**4892**	**9370**	**55,5**	**2,8**	**0,8**

(*) MIL 217 calendar failure rate with a simple mission profile but without correction

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3- Experimentation
Reliability engineering : missile example

- Analysis of FIDES reliability results by contributors allows to identify the potential improvements :

Electronic module (in fits)	for HR=70% contributors repartition	board	for HR=70%	For HR=30%
A	60% ΔT	board n°1	188 fits	131
	20% HR	board n°3	499 fits	462
B	50% HR 19% ΔT 14% therm.	board n°5	88 fits	45

Board failure rate in fits

- **↓ HR : failure rate /2 for module B**
- **Small gain for module A (major contributor is thermal)**

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3- Experimentation : ratio MIL / FIDES

- For different systems (MIL217 with mission profile) :

SYSTEM	Ratio MIL / FIDES System level	Dispersion Ratio board level
Radio	8	-
Telecom.	3.5	-
Autocom.	2	-
Cryptographic equipment	2.6	-
Missile A	3.6	1.6 to 6.2
Missile B	0.6	0.4 to 1.1
Rocket Air Force	3	2 to 8
Rocket Navy	4.5	2 to 40

➢ **No similar trend between equipments and less for boards and more less for components**

➢ **Finally no generic factor between MIL 217 and FIDES**

3- Experimentation : ratio NF/F

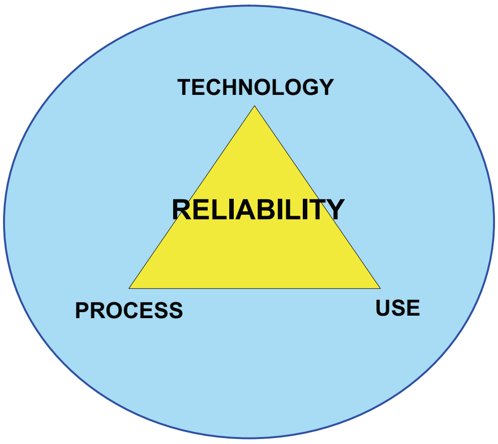
- For several equipments, we assessed ratio Non-Operating/Operating in order to have MIL = FIDES

Equipment	NO/O
Radio	1/20
Cryptographic equipment	1/15
Missile A	1/50
Missile B	1/10

➢ **No similar trend between equipment**

➢ **Finally : impossible to use a generic fixed factor NF/F as proposed in MIL traditional approach (RADC Reliability Toolkit 1993).**

4- Deployment



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4- Deployment : website

- The FIDES methodology freely available on website :
  - The FIDES guide (English and French)
  - The FIDES Group Excel sheets for an easy application of the methodology
    - A tool “part method”
    - A tool “board method”
    - A tool “process factor”
  - These tools can be downloaded directly at

http://www.fides-reliability.org

- The methodology will be proposed for standardization (IEC)
- It is already a French standard (UTE C 80811) in English language

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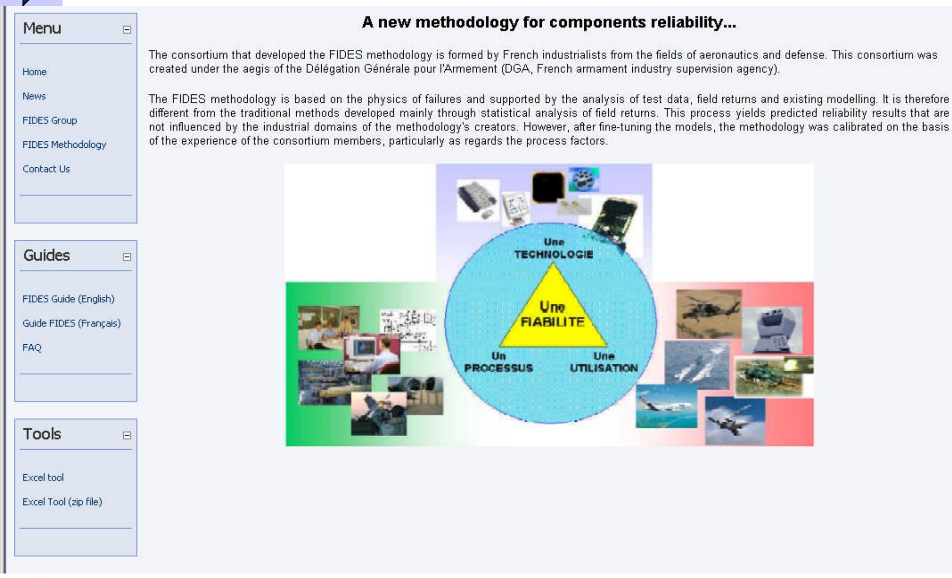
4- Deployment : FIDES web site



4- Deployment : positions of French contractors

- French MOD (DGA)
  - The FIDES Guide was integrated in the RNPA (Programs of Armament Standard Referential). It is quoted as a reference method in multiple new projects of armament.
- French spatial Agency (CNES)
  - This Agency realized a detailed evaluation of FIDES methodology. This evaluation concluded that FIDES can be used for space applications

  (see publications in " Actualités composants du CNES " n°17 in October, 2004 and n°18 in January, 2005).

Positions of French contractors

- AIRBUS
  - AIRBUS asks for a predictive reliability evaluation without requiring a method. FIDES is referenced and can be recommended.
- Automotive
  - FIDES group worked in partnership with the French Bureau of Automotive Standardization (BNA) during the elaboration of the FIDES Guide 2004.
- EDF group (French electricity provider)
  - EDF R&D realized an evaluation of the method, and has regular contacts with FIDES Group.

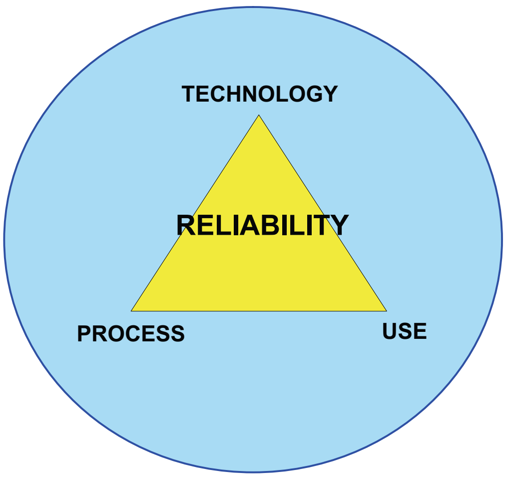
4- Deployment : international interest

- **Indicator of spread :**
  - Today, the Israeli company ALD proposes a FIDES module in its RAM COMMANDER software,
  - At the end of 2007, Norisko (DEKRA group) will propose also a FIDES module.
  - ITEM/RELIASOFT (US) and BQR (ISRAEL) are doing to develop FIDES module

International interest

- **Some publications outside France**
  - BOEING: IEEE MRQW 2004 - Manhattan Beach, CA, USA – December 7, 2004 "COTS Electronics Reliability“
  - RAYTHEON: Reliability and Maintainability Symposium (RAMS)- ALEXANDRIA, VA, USA January 24 - 27, 2005 "EXPERIENCE REPORT ON THE FIDES GUIDE RELIABILITY PREDICTION METHOD“
  - KEMET Electronic Corp. : Commercialization of Military & Space Electronics Conference & Exhibition - Los Angeles Airport, CA, USA - February 7 - 10, 2005 - Comparative Analysis of Military Standard to Commercial (COTS) Capacitors

5- Conclusion



5- Conclusion

FIDES provides

- A method for reliability assessment
- A method for reliability engineering

FIDES aims to cover all the industrial needs in matter of reliability prediction

FIDES has potential for evolution

- Integration of new technology without field experience
- Easy update of models

5- Conclusion

Major expérimentation conclusions

It is impossible to adapt MIL-HDBK-217 with a simple correction…

Takes into account overstress, mission profile (even for dormant applications), parts quality

FIDES is able to improve reliability by contributors analysis, and πprocess audit check list

New models are in progress such as asics, switch, hybrids, GaAs components, …

A maintenance structure is created to update methodology

Usable for all application fields (defense & civil) including space

Questions ?

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DLR Assessment Procedure of Commercial Parts for Space Use and First Experiences

29 October 2007
Jürgen Tetzlaff

Deutsches Zentrum für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

Content

- Status of ECSS COTS Document
- DLR Assessment Procedure
  - Overview on Key Elements
  - Assessment Summary (Key Elements)
  - DLR Risk Analysis & Control Procedure
- Successful Application of Approach
  - LCTSX (Experimental Mission – DLR)
  - Aladin RLH (IOV piggi-back on AEOLUS – ESA)
  - LCT GEO Relais Mission (pending – DLR)
- Tasks of DLR EEE Parts Department
- Running DLR EEE Parts Projects

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in der Helmholtz-Gemeinschaft

Status of ECSS COTS Document

- CNES and DLR developed a document for commercial parts: “General Requirements for the Use of Commercial EEE Parts in Space Applications“ (RNC-CNES-Q-60-523 = DLR-RF-PS-006).
- On base of this document, an ECSS document in parallel to ECSS-Q-60 should be created, but it was decided that the ECSS-Q-60B should be ready before. After that, a level 3 document in the Q-60 branch should be built up.
- Due to several problems and different interests in ESCC, the creation of ECSS-Q-60B takes a very long time (publication in July of this year), but some general points are already the same in both documents.
- Due to the long PSWG activity list and the limited resources, the level 3 COTS document will start within the next year.

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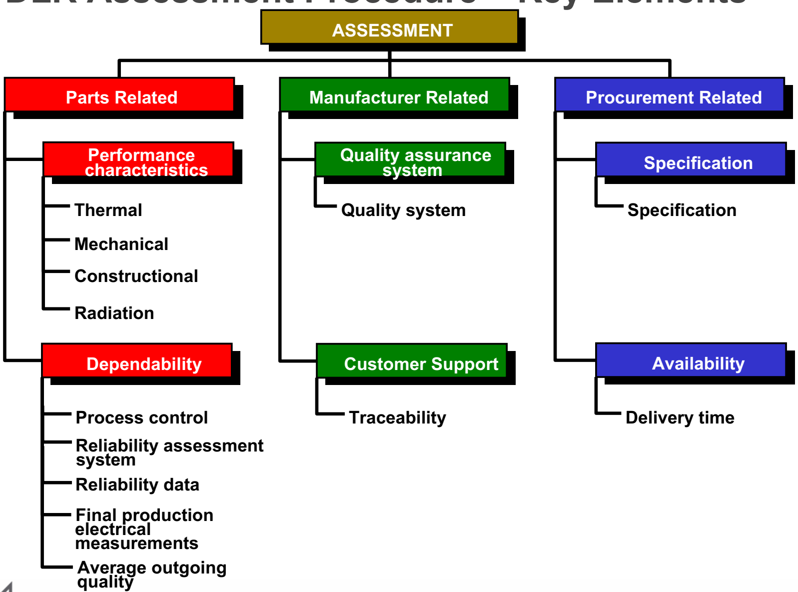
MEWS20_DLR.ppt > 3

DLR Assessment Procedure – Key Elements



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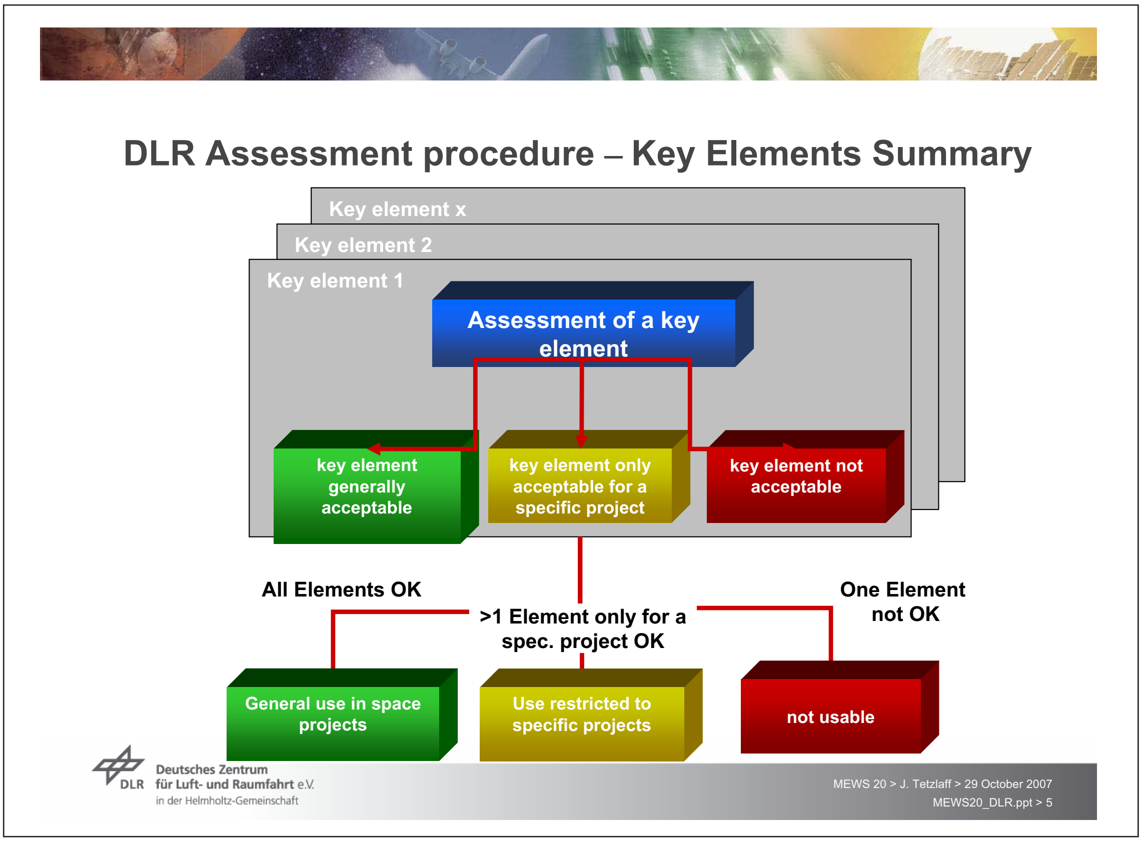

DLR Risk Analysis & Control Procedure (1)

- The basic assessment procedure was extended by a document which describes additional risk and cost analysis activities which can be used to refine decisions relating to the use of commercial components.
- The methods described are designed to be sufficiently flexible to allow their use for any component type and project, and this is achieved by giving qualitative guidelines to be followed during analysis rather than defining precise quantitative methods and criteria.
- It is not a self-standing document and is intended to be used only in conjunction with the basic assessment procedure document.

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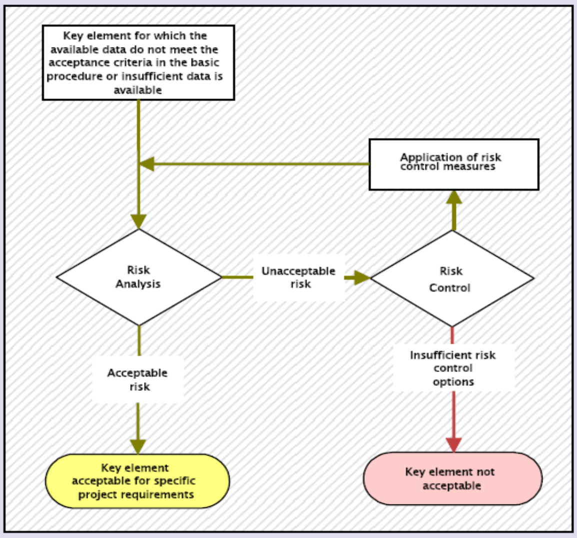
DLR Risk Analysis & Control Procedure (2)

- Approach for components to be used for a specific application even if a key element cannot be assessed as “acceptable”
  - Decide whether risk analysis is applicable,
  - Use all the available information and a standard risk diagram and scale to analyze the risk magnitude resulting from using a component with the “not acceptable” key element
  - Decide whether this magnitude of risk is acceptable for the specific project use
  - Decide whether risk control is appropriate
  - Identify any risk control actions which could be performed and assess the resultant reduction in risk magnitude
  - Decide whether the reduced risk magnitude is acceptable for the specific project use

DLR Risk Analysis & Control Procedure (3)



RISK ANALYSIS
Assessment of the risk and decision on acceptability

RISK CONTROL
Identification and application of measures to reduce the risk

Successful Application of Approach in Space Programs

- LCTSX (Laser Communication Terminal) – DLR Program
  - Assessment primarily focusing on optical parts or assemblies, for which no formal standard requirements exist
  - Assessment through internal PCB with reporting to DLR customer
- ALADIN RLH (Reference Laser Head) – ESA Program
  - Assessment through internal PCB
  - Review of referenced data and reports by prime contractor expert (with participation of ESA parts expert)
  - PADs approved by ESA after review of the assessment sheets and the corresponding reports and data
- LCT GEO Relais Mission – DLR Program
  - Similar approach as for LCTSX will be exercised
  - Known approach for the customer =► PAD approval process should be easier than the 1st time
  - Assessment activities and PAD approval still pending

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Summary

- Space application suitability assessment per DLR-RF-PS-003 has proven a viable and successful approach to accept the use of commercial parts on the basis of existing data and information obtained from a variety of sources (manufacturer, CPPA, user, etc. ...).
- Suitability of corresponding Risk Analysis & Control procedure needs still to be determined: to be used when specific parts are mandatorily needed for the application but have been assessed as not meeting all key elements.
- Collection and compilation of the assessment data and information is a tedious and time consuming task, such that the overall efforts and cost (of ownership) must be weighed against the cost of space qualified parts if available.
- The approach is well suited to formally approve non-standard and commercial parts for use in space applications when no standard evaluation, qualification, and screening requirements specifications exist.

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Tasks of DLR EEE Parts Department

- Elaboration of strategies to increase the availability of strategic components inter alia within the frame of the national participation to the ECI program (European Components initiative)
- Representation of German manufacturer and user interests in several bodies of the European Space Components Coordination (SCSB, PSWG, CTB and Executive)
- Determination and prioritization of the need of German users of EEE parts via regularly conferences (users and manufacturers)
- Information the German space industry regarding the availability of qualified EEE parts, respectively the required procedures for qualification
- Elaboration of strategies for the effective use of components and technologies in coordination with the space industry
- Initiation of EEE parts qualifications regarding the development of the space market (in the frame of the national budget)
- Monitoring the appropriate manufacturing processes of EEE parts (audits etc.)

Running DLR EEE Parts Projects

Activity	Term	Status
Qualification of Quartz and Oscillators	2005 - 2008	in process
Assembling of Radiation Resistant 2,5V-Regulators	2005 - 2007	nearly finished
Qualification of Shunt Resistors	2005 - 2007	nearly finished
Qualification of Microwave Connectors	2005 - 2008	in process
Qualification of Assembly and Test House	2006 – 2009	in process
Radiation Hardness Analysis MOSFETs	2006 - 2008	in process
Radiation Characterization of Commercial MOSFETs	2006 - 2007	nearly finished
Development of a GaN 1000V Switching Transistor	2006 - 2010	in process
Development of a CCGA Soldering Process	2007 - 2008	in process
Qualification of MMIC Local Oscillator	2007 - 2009	in process

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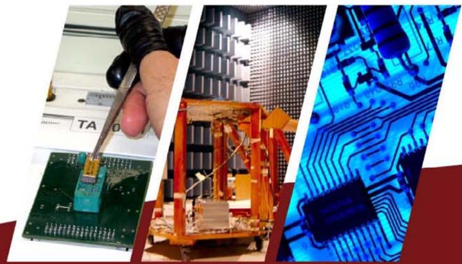

Presentation

Using commercial parts, understanding the risks and associated mitigating actions

20th MEWS, Japan

Presented by Geoffrey Penhaligon
Japanese Business Team Leader

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Presentation Content

- Pre-procurement Activities
- Supply Chain Management
- Parts Market and Quality
  - Root Differences COTS vs Mil
  - Operating Temperatures
  - Parts Selection
  - Source Selection
- Evaluation Testing
  - Typical Evaluation and Approval Program
  - Reliability and Qualification Program
- Obsolescence Management
- Procurement Activities
- Batch Acceptance
  - Batch Acceptance Program
- Change Process Control
- Lot Homogeneity
- Counterfeit parts
- Countering Counterfeit Parts
- Long Term Storage
  - Long Term Storage Risks
- Obsolescence Watch
- Contacts and ALTER Introduction

IGG Component Technology Limited

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Pre-procurement Activities

- Part Selection
  - Performance requirement
  - Environment
  - Life and Service
  - Operating and Storage requirements

  Preliminary selection
  - Datasheet Performance
  - Maximum Ratings
  - Operating & storage Temperatures
  - Quality Level
  - Procurement Specification

  Sample Evaluation
  - Constructional Analysis
  - Electrical Characterisation
  - Physical, mechanical and Environmental Evaluation
- Candidate review
  - Results of Evaluation
  - Finalisation of Procurement Specification
  - Primary manufacturer Selection

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Supply Chain Management

- The prime rule should be to purchase from a known proven supplier
  - Manufacturer Direct
  - Franchised Distributor
  - Parts Agency
- Line card Distributors, Wholesalers or other 3rd party Suppliers may list the manufacturer but an effective method of supply control may not be present
- It is very important to know and trust your Supply Chain and establish the controls necessary to limit the parts supply to recognised proven suppliers.
- The Military Market is having severe problems with Counterfeit parts , due mainly to the pressure of Obsolescence , cost and delivery resulting in Purchasing Departments expanding their Supply Chain and opening the doors to the fast gain, high profit Counterfeit Market.
- Purchasing Departments must maintain strict controls on their Supply Chain and avoid the apparent easy solutions as quick delivery, low price options offered by 3rd Party suppliers.
- Supplier should be
  - Established Parts Agency with a known proven procurement history
  - Manufacturer or Franchised Distributor
  - Established Quality Management System and registration with recognised Quality Approval Agency ie ISO
  - Membership to recognised Distributor Associations

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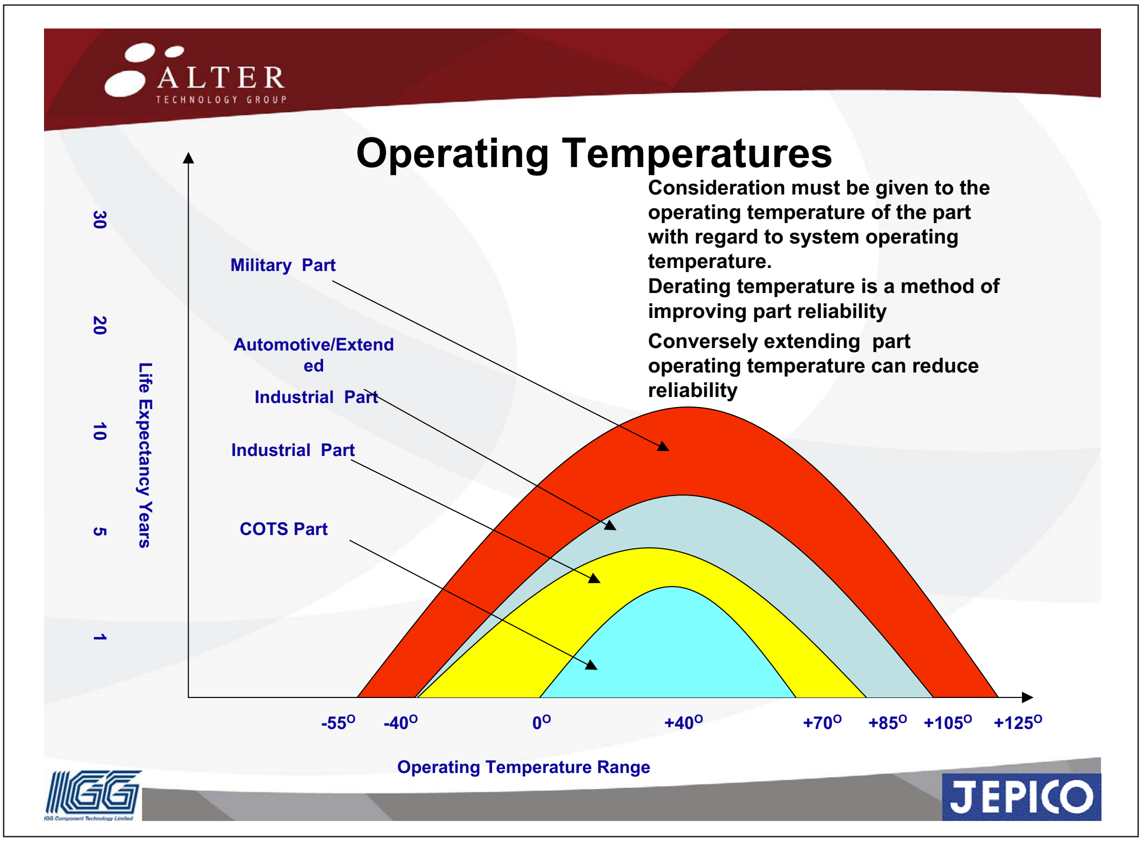
Parts Market and Quality

- Due to the declining Military parts market Customers are turning towards alternative sources
- The recognised parts markets are
  - Space&Military
    - Military Space Level Parts-QML-V-K
    - Military Level Parts-QML-H-S-M-Q
    - Manufacturer Military equivalent –883
    - Manufacturer Internal Specification
    - Agency or Customer Specification
  - Automotive
  - Medical
  - Industrial
  - Commercial
- The most obvious parts difference is Packaging,Operating&Storage Temperatures, Electrical & Physical characterisation, Screening but not necessarily quality
- Non Military qualified parts should be subjected to a Parts Selection Process and Evaluation to determine the suitability and capability of the part in it's intended application.
- Depending upon application Reliability and Qualification processes should also be considered to compliment Evaluation and Batch Approvals
- These are established processes developed over many decades and remain the most effective method of approving parts for high reliability applications.

Root Differences COTS vs Mil

The acknowledged components temperature ranges can be expressed as			
Military	-55°C	to	+125°C
Commercial	0°C	to	+70°C
Industrial	-40°C	to	+85°C
Automotive	-40°C	to	+105°C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Operating Temperatures
Consideration must be given to the operating temperature of the part with regard to system operating temperature.
Derating temperature is a method of improving part reliability
Conversely extending part operating temperature can reduce reliability
Military Part
Automotive/Extended
Industrial Part
Industrial Part
COTS Part
30
20
10
5
1
Life Expectancy Years
-55O
-40O
0O
+40O
+70O
+85O
+105O
+125O
Operating Temperature Range
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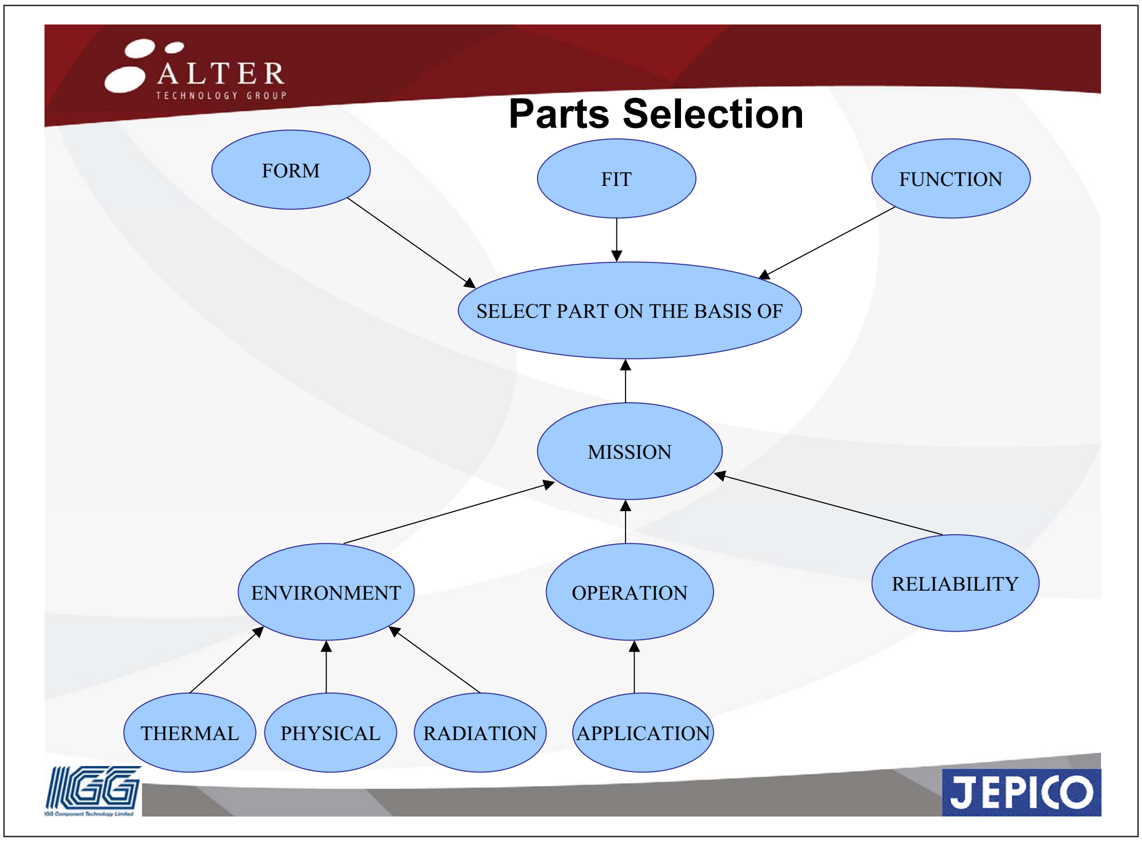
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Parts Selection
FORM
FIT
FUNCTION
SELECT PART ON THE BASIS OF
MISSION
ENVIRONMENT
OPERATION
RELIABILITY
THERMAL
PHYSICAL
RADIATION
APPLICATION
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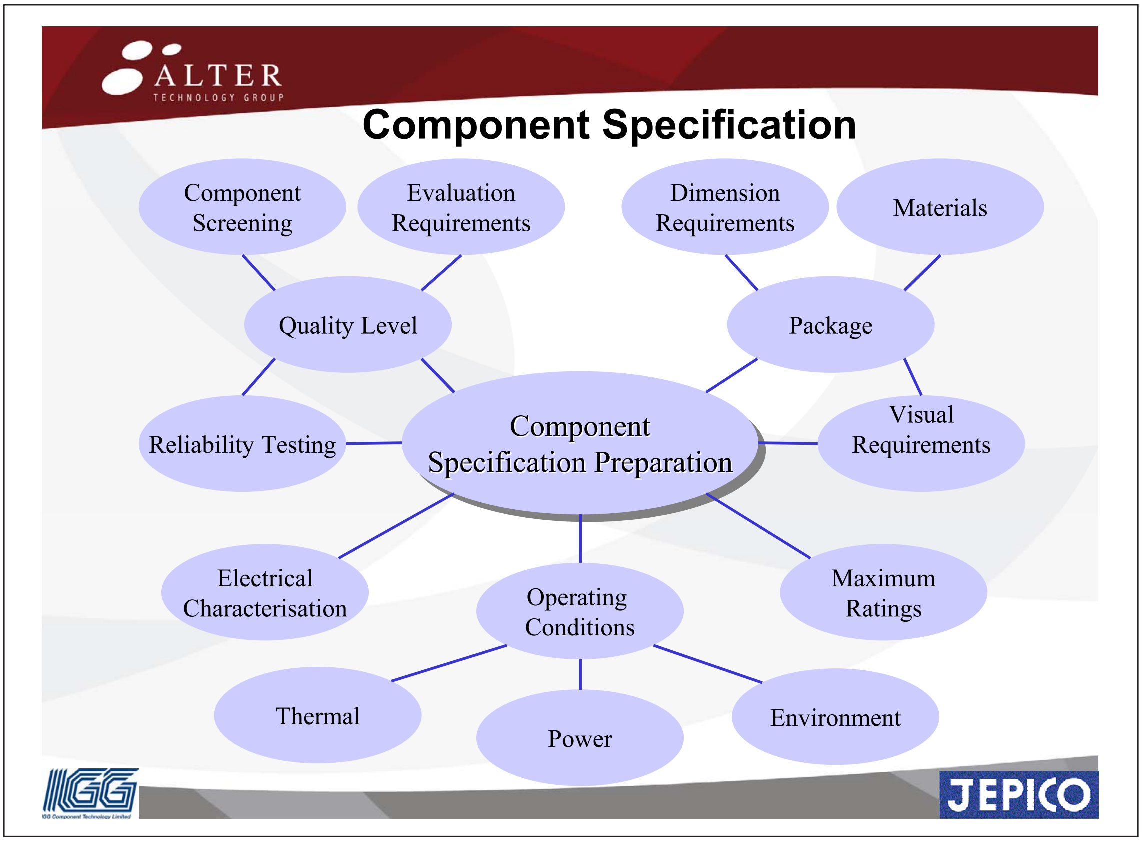
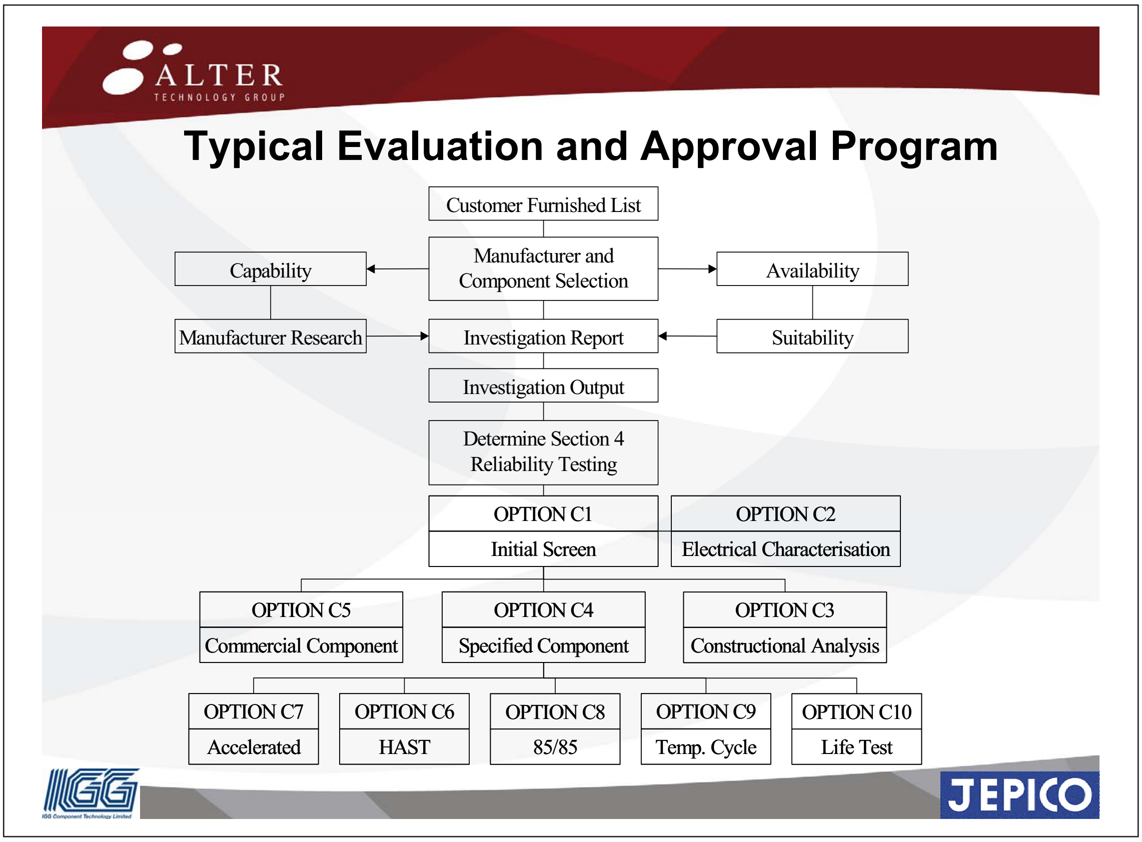


Evaluation Testing

- Where the intended parts procurement qualification or quality level does not meet the Project SOW requirement. Then parts should be subject to an Evaluation and or Reliability/Qualification Program to assess the parts suitability and capability for the intended application.
- Parts Selection is not just a case of Form, Fit & Function, other considerations including
  - Reliability
  - Environmental, Physical, Mechanical and Electrical Characterisation
  - Suitability and Capability
- All have to be assessed in order to confirm that the part meets the application needs.
- This is very much the case when considering COTS as suitable candidates
- The prime component selection philosophy should remain to select parts which have an established capability.
- Where this is not possible then a Parts Evaluation should be performed.
- Parts Evaluation Programme should contain the necessary test elements to confirm the suitability and capability of the part to operate in the proposed application.
- A typical Evaluation Phase follows, though it must be stated that each Evaluation should be designed baring in mind the parts technology, classified market, quality, history and intended application.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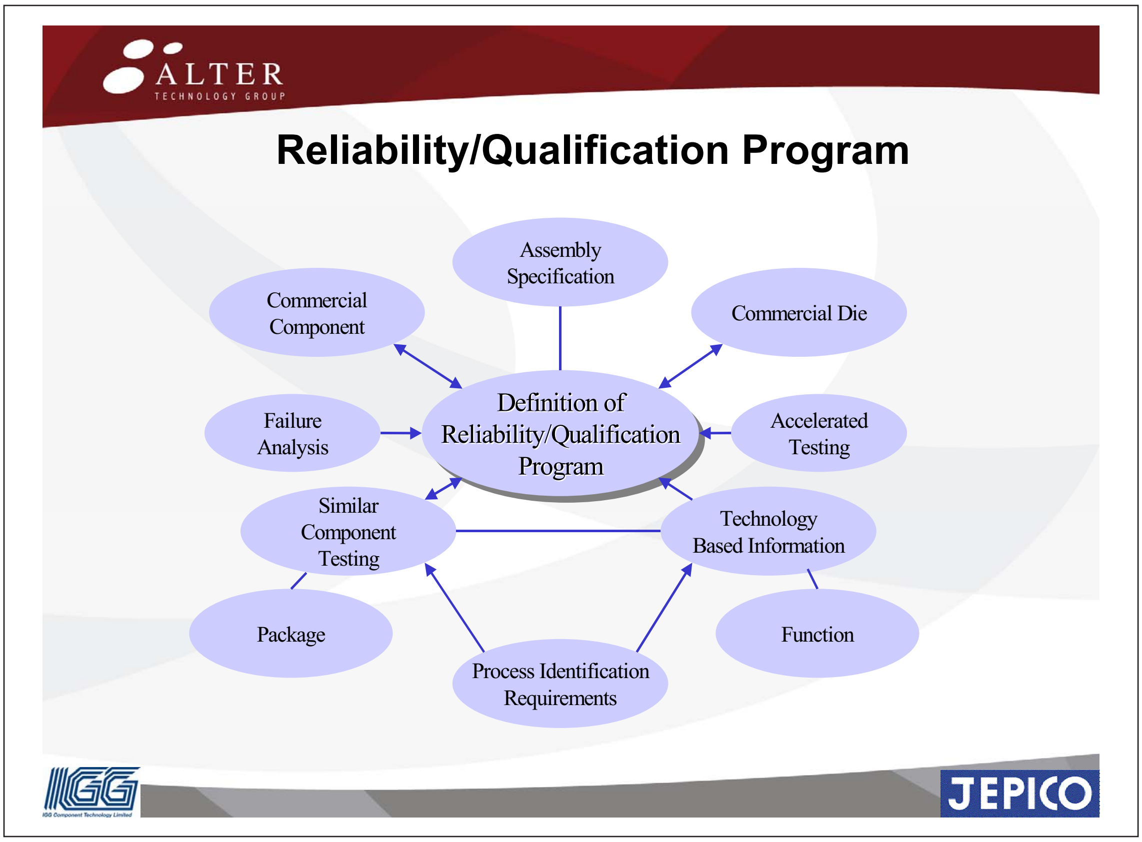
Typical Evaluation and Approval Program
Customer Furnished List
Capability
Manufacturer and Component Selection
Availability
Manufacturer Research
Investigation Report
Suitability
Investigation Output
Determine Section 4 Reliability Testing
OPTION C1
Initial Screen
OPTION C2
Electrical Characterisation
OPTION C5
Commercial Component
OPTION C4
Specified Component
OPTION C3
Constructional Analysis
OPTION C7
Accelerated
OPTION C6
HAST
OPTION C8
85/85
OPTION C9
Temp. Cycle
OPTION C10
Life Test
JEPICO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Reliability/Qualification Program
Assembly Specification
Commercial Component
Commercial Die
Failure Analysis
Definition of Reliability/Qualification Program
Accelerated Testing
Similar Component Testing
Technology Based Information
Package
Function
Process Identification Requirements
JEPICO

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Obsolescence Management

- Obsolescence Management is understanding the Supply Chain, the Market situation, Availability and Customer needs
- Space Projects are mainly immune to Obsolescence, since each Project generally speaking has a specific design and a single procurement and production phase, this results in a single custom procurement within a specific time frame.
- Some Space Projects can be susceptible to Obsolescence, these include all Space Projects where the Customer wishes to maintain a system design over a given number of productions. This is the situation in the case of a Customer Standard Equipment/System or repeated productions associated with Launchers, H-IIA-B, HTV or a Satellite Series or Satellite Network/ Constellation where multiple productions over time are foreseen.
- In these cases decisions on the continued availability of the part verses the future needs of the Project have to be weighed against the risk associated with future availability, obsolescence and change notices.
- There are also risks associated with Single or Multiple Procurement these have to be weighed against continued part availability, obsolescence, cost, long term storage and relife risk.
- When considering the Single or Multiple Procurement risks, attention must also be given to
  - Continued Availability of Datasheet, Specifications, Test Capability,Records
  - Future quantity needs I.E production, spares, maintenance, repairs, relife,investigation
  - Method of assuring Long Term Storage of parts, Information Records and Test Capability

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Procurement Activities

- Assuming that the Supply Chain has been proven and that the Parts Selection has been performed then Procurement can proceed.
- The results of the Supply chain review should have identified suitable suppliers and only these should be used.
- Problems will arise if at the time of Procurement the Purchasing Departments are given a mandate to obtain the very best price and delivery. Under such directives there is the risk that proposals will be obtained from unknown or untested sources
- Purchasing Departments must maintain strict controls on their Supply Chain
- The procurement from unapproved or 3rd party suppliers introduces many risks associated with the continued support of the part and risks associated with Counterfeit parts
- In Europe Space Customers are advised to procure on from Manufacturers, Franchised Distributors and Parts Agencies
- Care should also to be taken to specify the part by direct reference to Datasheet revision/issue, a simple specification sheet or a known date code/die revision(if strictly required following performance of Evaluation)
- Some part suppliers do not welcome parts approval, up-grading or up-screening of their products especially for high reliability applications
- Care must be taken with repeat procurements to ensure that un-notified COTS production changes have not been invoked which will invalidate previous documentary evidence and Evaluation results.

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Batch Acceptance

- In some cases the entire future Production quantity may be procured as a single procurement lot and subjected to an Evaluation or Reliability/Qualification program
- In this case the performed Evaluation will authorise/qualify the entire Procurement Lot
- Where the Evaluation was performed on a specific sample prior to the Procurement Phase then the new Procurement Lot will require a specific Batch Acceptance Test to be performed.
- The main consideration with separate Evaluation Procurement Lots is ensuring that the part has not been subjected to any changes in assembly process or materials, since this will invalidate the Evaluation, resulting in the need to repeat the Evaluation on the new Procurement Lot.
- To assure that no changes have taken place since the previous Evaluation it is important that the Purchasing Department specifies the required part and that once the Procurement Lot has arrived that a correlation Constructional Analysis is performed.
- This Constructional Analysis is designed to produce a detailed examination of the part construction and materials thereby establishing if any changes have been made since the previous Evaluation or procurement.
- A typical Batch Acceptance sequence follows.

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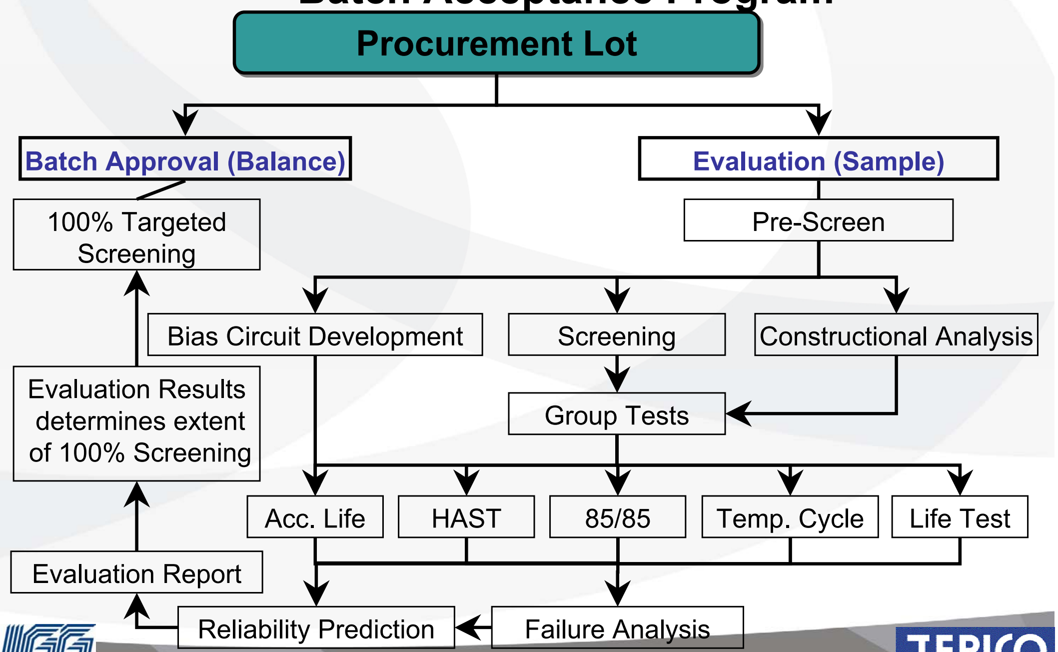
Batch Acceptance Program



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Change Process Control - 1

- Space Projects rely upon qualification and heritage (previous usage/history) as being the basis for Established Reliability.
- Established Reliability relies upon one major point, that is that there is strict change controls in place to prevent part changes which will void the established history.
- The parts performance is therefore defined by the issued specification while its maintenance is assured by the fact that manufacturers have to justify or qualify each change to their design, assembly, production process or materials.
- Since Military parts have to adhere to this standard, the Customer can ultimately rely upon the established reliability of the part through continuity of manufacturing
- Military parts cannot change their process without issuing a Product Change Notice
- Military parts require Obsolescence Notice of 1- 2 years
- COTS manufacturers can change materials, production and assembly processes without notification
- Datasheets may change or disappear, parts may become obsolete
- COTS parts do not employ single lot controls
- Part Approval Programs have to be continually repeated due to part process and material changes
- The Aircraft industry have introduced a controlling AQEC standard for COTS
- In response the DSCC has introduced a new VID specification category
- These are voluntary programs where Manufacturers confirm performance, materials and limit changes

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Change Process Control - 2

- DSCC have introduced a new specification category for COTS products.
- Specifically, commercially available microcircuit products are being documented for the first time on a standardisation document.
- Use of these DSCC VIDs will avoid the use of manufacturer generated specification control drawings (SCDs) or manufacturer's drawings and avoid the potential proliferation of non-standard products.
- The participating manufacturers have agreed to provide information and services that have not traditionally been associated with COTS products.
- Current Supplier's Program Benefits include, under a Single Standardisation Document within a controlled baseline:-
  - Enhanced product change notification of processes, materials, electrical performance, finish, molding compounds and manufacturing locations.
  - Extended temperature performance.
  - Enhanced Pedigree - Reliability and electromigration checks, electrical characterization over temperature and confirmation of package performance over temperature.
  - Enhanced Obsolescence Management, including notification period
  - Moisture Sensitivity Information

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Lot Homogeneity

- Generally Commercial parts do not have any regulation to control lot homogeneity other than the self-regulation and the DSCC VID registration.
- This means that commercial parts produced within a single Procurement Lot may not utilise the same design, process and materials
- IGG has experienced receiving different package sources and die sizes within the same procurement lot.
- Since any variation in design, process and materials will invalidate previous Evaluation results it is very important to ascertain the lot variance before performing Evaluation or Batch Acceptance Testing
- Clearly it would be useful to contact the manufacturer and determine if any variation or changes have been made. Procurement against a VID specification will help to control this variation
- Procurement against a Datasheet Issue/Rev will not necessarily assure that parts have been manufactured with the same design/process/materials
- There are a number of non-destructive tests which can be performed to identify a baseline condition of the parts and inspect the procurement lot for lot variation
- Once lot variations or homogeneity has been established the proposed Evaluation and Batch Acceptance can be adjusted accordingly
- It is possible to adjust the Evaluation and Batch Acceptance testing to compensate for the identified lot variation and produce an acceptable Procurement Lot
- Constructional Analysis can be used to verify of the design, process and material variations to a degree and establish the baseline for future examinations.

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Lot Homogeneity - examples

The original (obsolete) diode

The 'COTS' replacement

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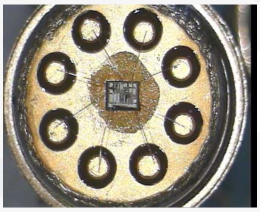
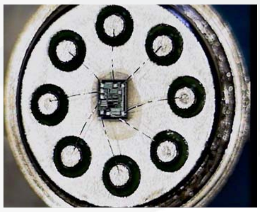
Lot Homogeneity - examples

Same Date Code



Different Headers



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Counterfeit Parts

- Counterfeit parts are now the biggest problem in today's Military parts market
- It remains a major concern for the Space Market though the procurement and Purchasing controls employed within the Space Market are currently managing the risk Counterfeit parts will continue to be a major concern.
- The Military Market is flooded with counterfeit parts due to the pressures of Obsolescence and in many cases urgent delivery, declining availability and lower cost, parts are being procured from unknown or unproven supply chains in order to satisfy budget and production requirements
- In fact even proven supply chains have been duped by previously reliable sources to introducing counterfeit Military parts into the Military Market in some cases unknowingly increasing the presence of counterfeit parts in the supply chain.
- If Purchasers remain within the 1st and 2nd tier Military Parts Suppliers including Manufactures, Franchised Distributors and Authorised Parts Agency then the parts supply is in most cases underwritten and guaranteed
- If Purchasers or indeed Distributors turn to suppliers outside of this inner circle then the risk of receiving counterfeit parts is very high
- Counterfeit parts come in many forms
  - New productions using cheap or in some cases no die
  - Recovery of scrapped parts(these are the real parts but previously found to fail but find there way back into the market) these are the hardest counterfeit parts to identify since they are essentially physically the same as genuine parts.
  - Remarked parts comes in many forms starting with parts from cheaper sources and marked with higher quality part numbers or simply adding higher quality codes to existing commercial parts

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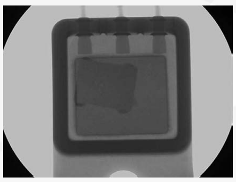
Countering Counterfeit Parts - 1

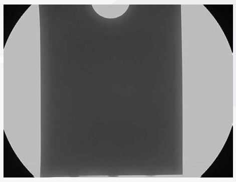
- There are a number of established methods of countering the presence of counterfeit parts.
- These methods include both destructive and non-destructive means
  - Supply Chain and Source Controls
  - Beware of unreasonably priced offers
  - Most legitimate Suppliers will offer sale and return guarantees in the event of failure(though the incidence of Franchised Distributors citing Non-refundable/ Non Cancellable T&C's are increasing)
  - Documentation, Manufacturers CoC(most Suppliers/Manufacturers will accept to verify if a given part number and lot date code exist, though this does not necessarily prove the heritage of the received procurement lot)
  - External and mechanical inspection(careful performance of external visual and mechanical dimensions may reveal deviations not previously seen on the manufactured part)
  - Parts Package traceability information(comparison with legitimate Manufacturers packaging and packaging is a valuable tool)
  - Delivery Documentation other than CoC(Manufacturer Advice notes and Delivery slips can also be inspected against known formats)

Counterfeit Parts - examples

Both samples carry BeO warnings but



This one is transparent in x-rays



This one isn't

Beryllium Oxide (BeO) is opaque to x-rays.

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Countering Counterfeit Parts - 2

- Weight(if sufficient statistical data is available this may be used as a course gauge)
- Solderability(condition of lead solder and the results of solderability may indicate problems)
- CSAM(IGG has shown in the case of plastic parts, variations in the package filler and paddle construction pointing to counterfeit packaging)
- X-ray(IGG has been able to map the internal construction including bonding and die orientation leading to identification of counterfeit parts)
- Fine&Gross Leak(useful tool to identify parts with substandard assembly leading to identification of counterfeit parts)
- EM-Room(can be used to confirm correct part function but is not 100% effective confirmation since some counterfeits are remarked commercial parts which provide correct functionality at room temperature but fail at temperature extremes)

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Countering Counterfeit Parts - 3

- RM-Hi-Lo(a very good guide to military temperature range operation and will identify remarked commercial parts)
- Marking Permanence(an efficient method of identifying remarked parts but not conclusive when sophisticated re-marking is used)
- Mechanical Integrity(lead pull and package integrity have also been used to identify substandard assembly)
- PIND(will identify poor assembly but cannot be used to uniquely identify Military parts, remains a useful tool)
- Decap(can be used to very construction and die topography including importantly die numbers, revisions and lot codes)
- Microsection(can be used to assess design, construction and materials either as an investigative or as a comparative tool)
- Accelerated Tests;HAST, 85/85(these may be used to verify the harsh environment performance and confirm Military part performance)

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Countering Counterfeit Parts - 4

- Counterfeit parts will continue to threaten the Space market because of the huge profits which can be made by selling parts up the market to Space level where profits of many thousand times can be made very quickly.
- Selling a commercial part costing cents as Space Grade can net hundreds if not thousands of dollars a part.
- Manufacturers will cooperate with Parts Agencies and Customers in identifying these parts and removing them from the market place.
- Manufacturers are in many cases willing to verify parttypes against lot/date codes wherever possible(this has previously been difficult, but manufacturers are becoming more aware of the need to participate in the counter programs) But this alone is not sufficient
- Supply Chain Management, procurement & documentation controls,the performance of Receiving Inspection followed by Destructive Physical analysis and in some cases comparison with statistical/baseline documentation formats, design, construction, assembly and material data will continue to be the best protection to prevent counterfeit parts entering your production line.
- Finally, once a counterfeit is suspected or confirmed inform the Supply Chain, Customer, Manufacturer, raise the national NCR/Alert and confirm final disposition/destruction of parts. Revise Supply Chain Control and Counter Counterfeit Measures accordingly.

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Long Term Storage

- Where single or multiple productions are planned within a single procurement then the ability to store parts over a long period has to be considered
- Long Term Storage is not placing the parts on a shelf and forgetting them for years
- Customers who have taken such risks have suffered greatly from the poor reliability of the parts to the increased costs of additional procurements and the effects of obsolescence on their design stability and future production schedules.
- If significant procurements are planned then Long term Storage must be viewed as being similar to taking out insurance
- If the insurance option is not taken up, then there is a greater risk of loss of the investment and the high probability of significant additional costs associated with investigation, replacements, alternatives, re-design, re-qualification and delayed production
- It is therefore very important to specify and control the Long term Storage process
- IGG has over many years developed a process based upon our own experience and that of our Customers, some of whom have experienced the fallout from poor Long term Storage controls.

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Long Term Storage Risks

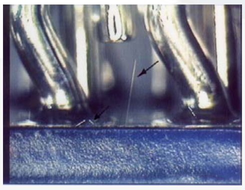
- **Degradation or deterioration during stock holding will vary from little or none to severe, according to a number of parameters which include:**

Part Related

- Component technology
- Component package
- Lead material
- Packaging and intermediate packaging
- Extent of handling prior to storage
- Cleanliness of part
- ESD

Storage Related

- Temperature stability
- Humidity stability
- Duration
- Handling
- ESD
- 'Dry' sealed packaging
- Special considerations, magnetics etc.



Tin Whiskers

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Long Term Storage Risks

- **The threat to the stored parts is obvious but many other factors will result in either a risk to the part or a real threat to the continued use of the part.**
- **The main threats can be summarised as follows.**
  - **Provider,security,insurance**
  - **Procurement Documentation**
  - **Datasheet & Specification**
  - **Alerts NCR's and Failure Analysis**
  - **Change notices**
  - **Obsolescence**
  - **Inspection and Test**
  - **Handling and ESD**
  - **Packaging**
  - **Traceability and Stock Control**
  - **Part consumption, spares etc**
  - **Store environment**
  - **Store monitoring,Audit**
  - **Relife**

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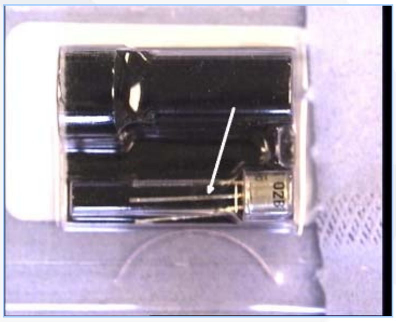
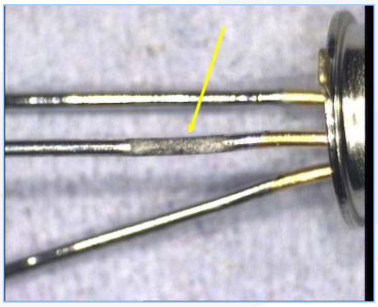
Long Term Storage - examples



Lead (Pb) in the leadout finish has been oxidised by the antistatic finish on the shipping package



Subsequently IGG have undertaken repackaging all product in bulk or solid anti-static material.

Effects of poor Long Term Storage controls

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Obsolescence Watch

- Once a Commercial part is selected it is important to remember that Commercial parts are not subject to any formal change or cancellation notification period.
- This means that it is up to the individual Manufacturer what level of notice is given to either current customers or the market in general.
- Therefore if a Commercial part is procured against a future need or designed into a future product it will be susceptible to change or cancellation
- It is therefore necessary to establish an Obsolescence Watch, to identify if the product is subject to change or whether further Customer procurement is required
- Where Customers have secured their future needs and established a Long Term Storage capability, it remains important to understand the market movement of the part, its future production, part changes or planned obsolescence are all factors which will affect even the held stock
- Any change by the Manufacturer may be an early indication of a problem with the current stock. Customers may have to evaluate the change and determine if the change effects the stock or whether a new procurement is necessary
- It may also be the case that last time buys may be used to top up existing stocks or protect the availability of the current part design
- Any change to the part will invalidate the established approval program and incur additional costs.

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ALTER TECHNOLOGY GROUP

Alter Introduction

- ALTER Technology Group established in January 2007.
- The ALTER Group was formed by the merger of the following companies
  - TECNOLOGICA Spain (Seville/Madrid)
  - IGG UK and US (Fareham/Valley Forge)
  - TOP-REL in Italy (Rome/Bari)
  - HIREX Engineering in France (Toulouse)
- ALTER Group is an European leading company specialised in the field of part engineering, testing, quality and procurement for Aerospace and Defence and other industrial applications.
- ALTER Group is also the European market leader for EEE parts for high reliability applications.
- The individual ALTER companies will continue operating in their geographical locations within an integrated organisation structure to implement the group synergies.
- Maintain laboratories in UK, Spain, Italy and France.
- Our highly specialised services range from the electronic part evaluation, procurement and acceptance, to equipment certification (EC marking) and electromagnetic compatibility engineering.
- A solid specialised technology base, permanent innovation and quality assured to ISO 9001, more than 189 professionals and revenues in excess in 2006 of 44 M€ are the pillars sustaining our company.

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Alter Introduction-continued

ALTER is an European leading company specialised in the field of part engineering, testing, quality and procurement for Space, Aerospace & Defence and other industrial applications certified to ISO-9000-2000. Our highly specialised service range from the electronic part evaluation, procurement and acceptance, to the equipment certification (EC marking) and electromagnetic compatibility engineering.
A solid specialised technology base, permanent innovation and quality, more than 189 professionals are the pillars sustaining our company.

Tecnologica is based in Seville and Madrid in Spain,was established in 1986. In 1993 the headquarters and laboratories were moved to Seville. Expansion of service portfolio to include the engineering and certification of industrial equipment. Operating in space, defence, telecommunications and industrial markets employing 87 highly trained and qualified staff in Seville and Madrid offices

IGG, a UK based independent, private company, established in 1978 and dedicated to supporting Customers needs in 19 countries. IGG employs 44 highly trained and qualified staff in UK and USA offices, specialists in all types and every aspect of hi-reliability parts. Innovators in the use of all part Quality levels for all applications operating in space, aerospace and defence & industrial markets and a service provider for part users & manufacturers

Toprel is based in Rome, Italy and was established in 1988, with the main objective of supplying services to space industries in the field of EEE high reliability parts.
Employing 24 highly qualified staff including part engineers specialised in the field of Hi-Rel parts with large experience in space projects and technical experts in the field of parts testing, semiconductor physics, radiation, failure analysis.

Hirex is based in France, was established in 1993 employs 34 highly skilled and trained engineers and technicians with cumulative expertise in high-reliability space parts, experts in semiconductors physics, parts manufacturing, board and test systems design, technology and device construction, radiation effects and testing, within a new facility of 1700 m².

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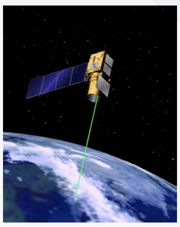
Japanese Projects

2006 GOSAT Superbird
2005 JEM-Smiles,MAXI, HTV
2004 WINDS, SOLAR-B, Planet-C
2003 SELENE, H-IIA, Galaxy-E
2002 MTSAT-2, ASTRO-F
2001 SERVIS, MTSAT-1
2000 ETS-VIII, PALSAR
1999 ALOS, USERS,
1998 MDS-1, ASTRO-E
1997 DRTS Planet-B
1996 Oicets JFD
1995 Adeos-II H_IIA Lunar-A
1994 ASTER
1993 SFU
1992 ETS-VII
1989 COMETS



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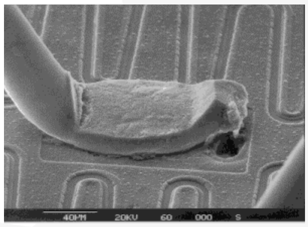
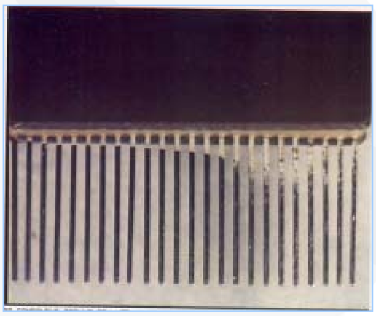
Alter Introduction-continued

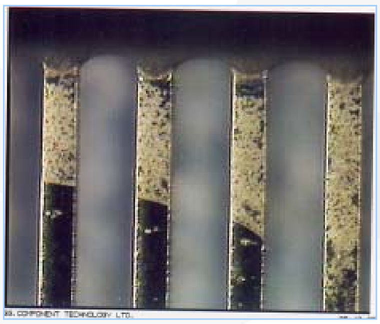
- COTS and PEMS Qualification
- Upscreening / Upgrading / Uprating
- Evaluation of New Products
- Engineering and Consultancy
- Customer Training
- Parts Procurement Management
- Laboratory Services
- Obsolescence Management & Solutions
- Long Term Storage
- Kitting / Consolidated Inventory
- BOM monitoring
- Counterfeit Identification / Screening
- Grey market Qualification & Mitigation



Long Term Storage - examples



Examples of poorly solder finished leadouts exposing pure tin near the microcircuit package



Effects of poor Long Term Storage controls

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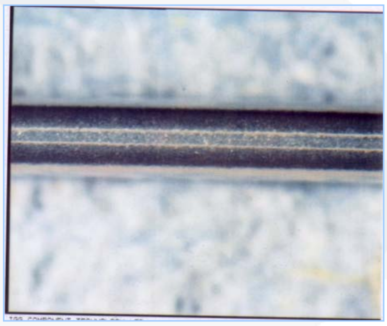
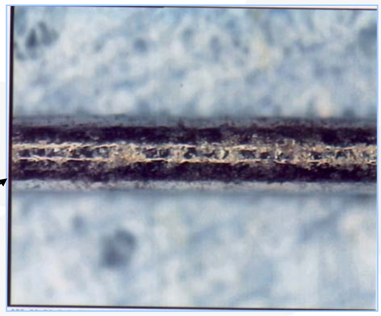
Long Term Storage - examples

Good solderability





Poor solderability

Effects of poor Long Term Storage controls

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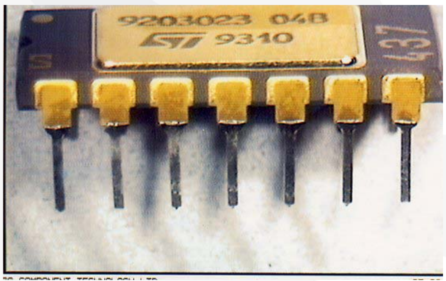
Long Term Storage - examples



Effects of poor Long Term Storage controls

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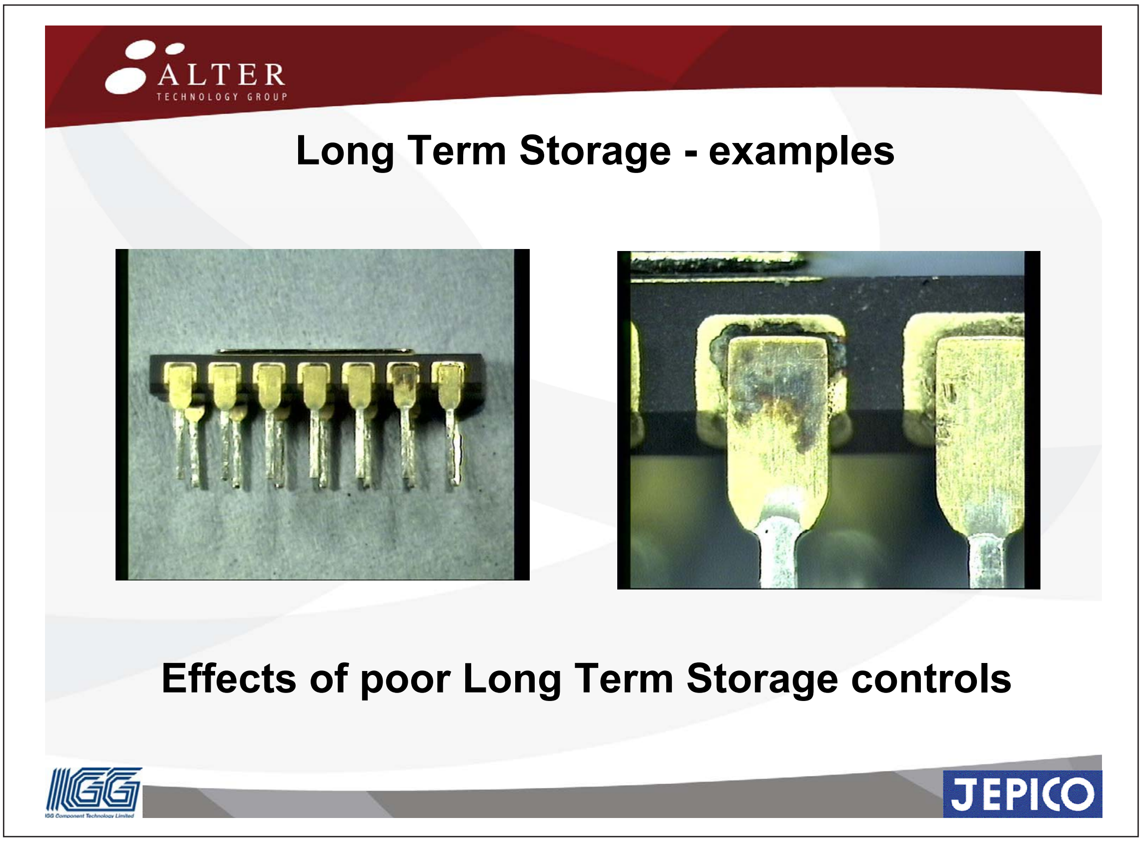
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Long Term Storage - examples
Effects of poor Long Term Storage controls
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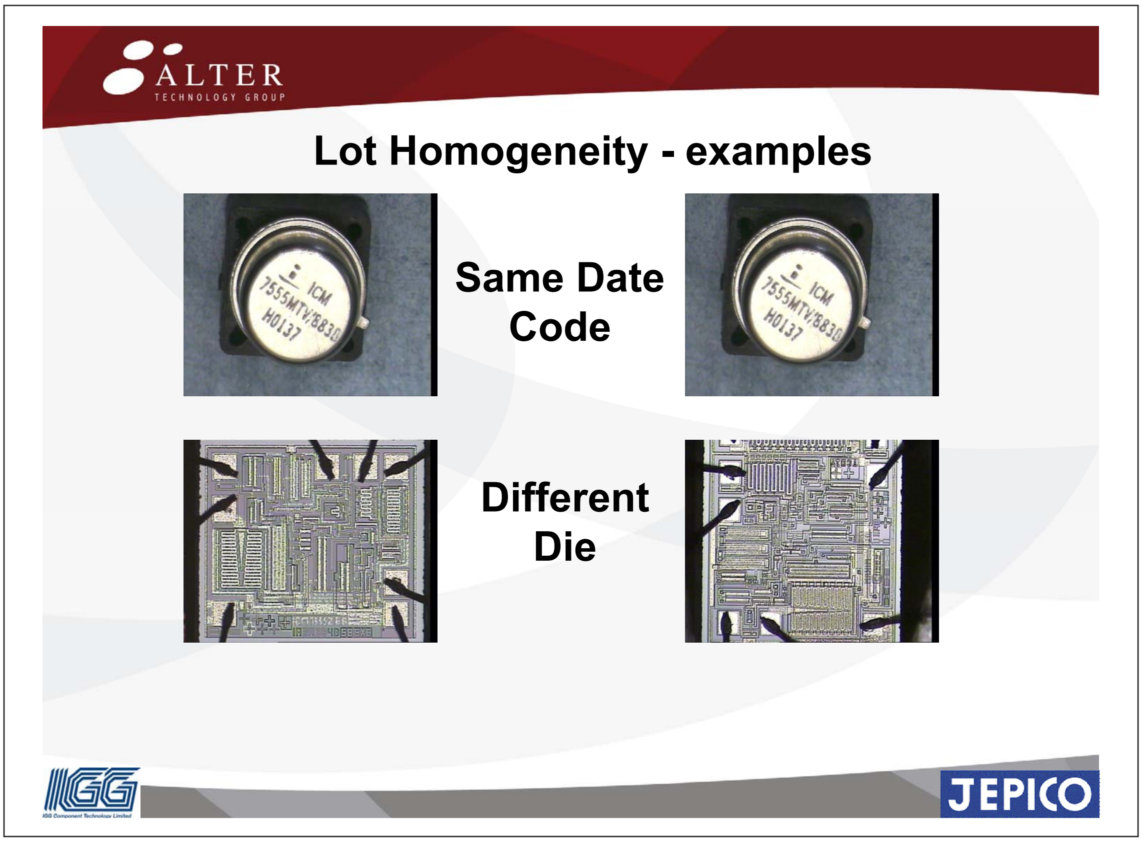
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Lot Homogeneity - examples
Same Date Code
Different Die
ICM
7555MTV/883C
H0137
JEPICO

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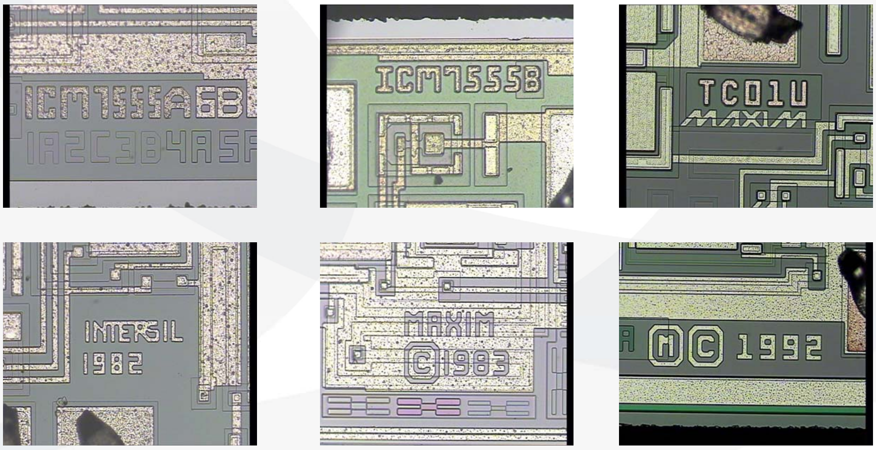
Lot Homogeneity - examples



In eight samples the user had two manufacturers and six different die revisions.

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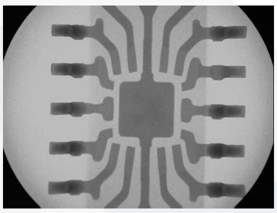
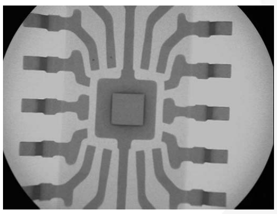
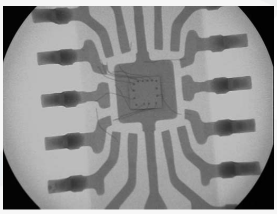
Counterfeit Parts - examples



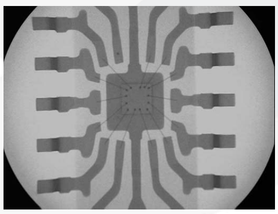
No Die



No Bond Wires



Incorrect Bonding



Incorrect pin assignment

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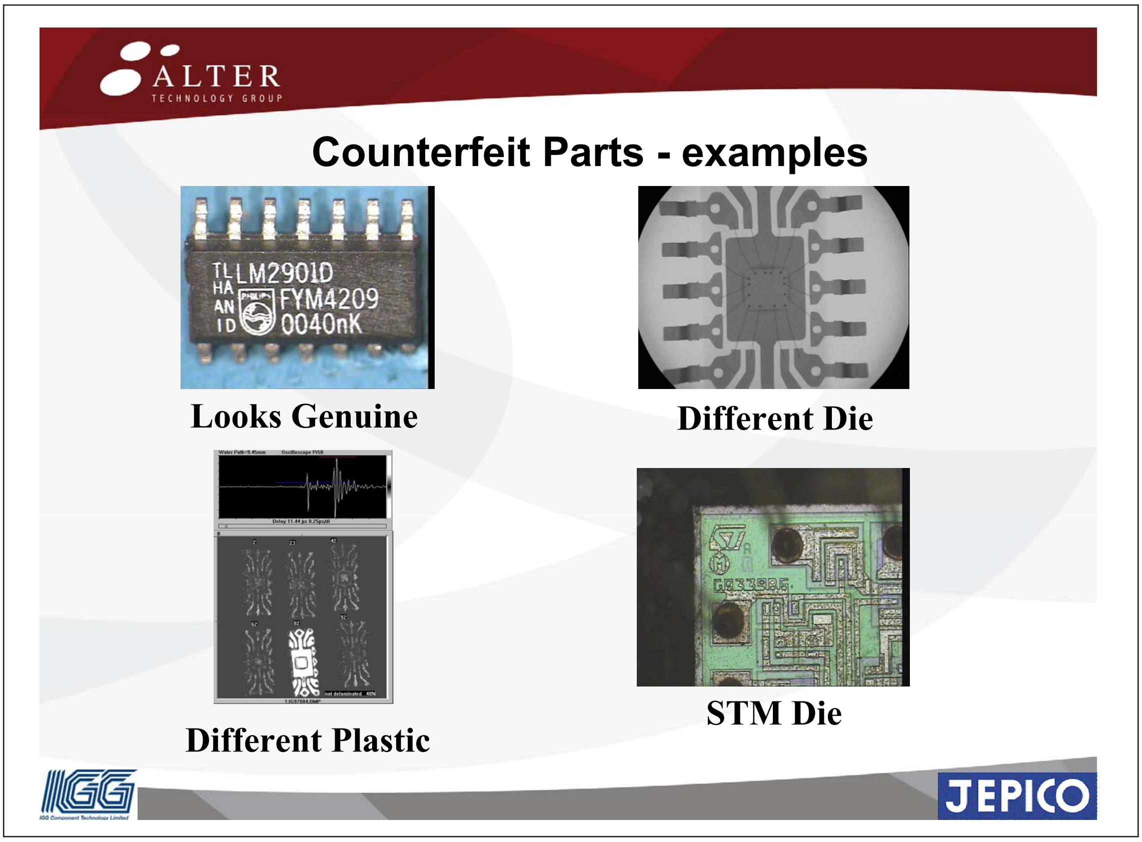
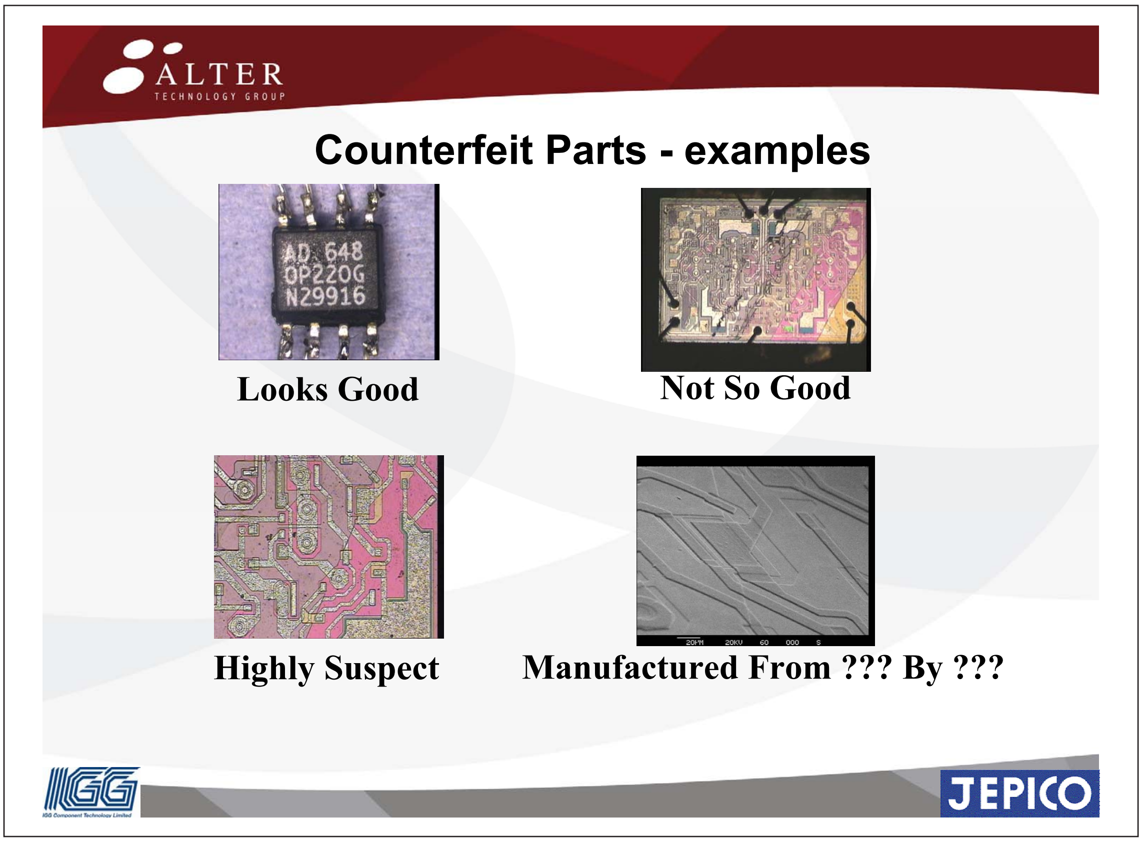

ALTER
TECHNOLOGY GROUP
Counterfeit Parts - examples
LM2901D
FYM4209
0040nK
Looks Genuine
Different Die
Different Plastic
STM Die
IGG
JEPICO


ALTER
TECHNOLOGY GROUP
Counterfeit Parts - examples
AD 648
OP220G
N29916
Looks Good
Not So Good
Highly Suspect
Manufactured From ??? By ???
IGG
JEPICO

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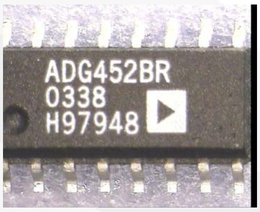
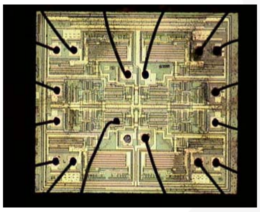
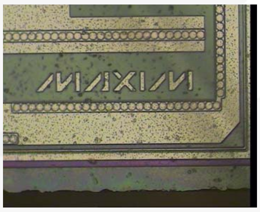
Counterfeit Parts - examples







What you see is not always what you get.

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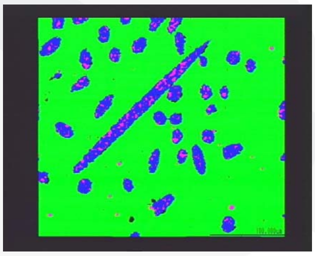
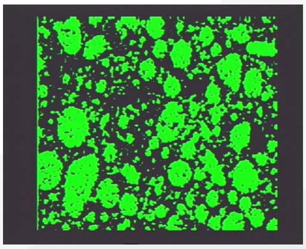
Counterfeit Parts - examples

DO FILLERS VARY THAT MUCH?
Two examples are shown in microsection below



ACTEL



ZETEX

There is no problem with these encapsulants but they illustrate the differences which may occur.

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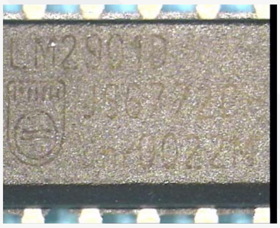
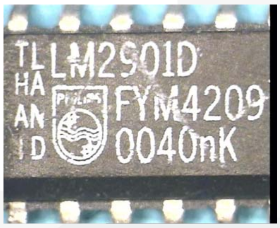
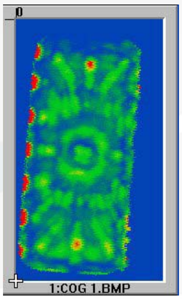
Counterfeit Parts - examples

SCANNING ACOUSTIC MICROSCOPY & ENCAPSULANT IDENTIFICATION

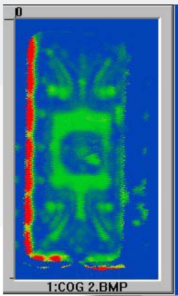


The markings of the two samples used for comparative SAM





	LH	RH
T_{AMB}	19°C	19°C
Power (Db)	28dB	34dB
Interface (us)	27.03	26.68
Length (us)	1.43	1.43
Delay (us)	0.34	0.36
Width	0.71	0.71



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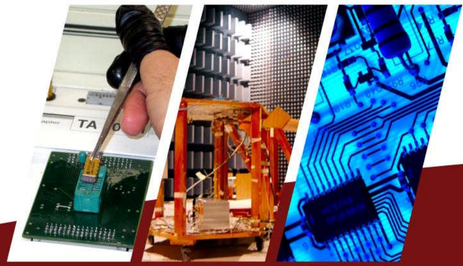

Presentation of European Manufacturers
20th MEWS, Japan

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Presentation Content

- ALTER Introduction
- Presentation Objective
- Introduction to European Space Agency (ESA)
- ESA QML
- ESA QPL
- ESA EPPL
- European Manufacturers with Space Capability

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ALTER TECHNOLOGY GROUP

Alter Introduction

- ALTER Technology Group established in January 2007.
- The ALTER Group was formed by the merger of the following companies
  - TECNOLOGICA Spain (Seville/Madrid)
  - IGG UK and US (Fareham/Valley Forge)
  - TOP-REL in Italy (Rome/Bari)
  - HIREX Engineering in France (Toulouse)
- ALTER Group is an European leading company specialised in the field of component engineering, testing, quality and procurement for Aerospace and Defence and other industrial applications.
- ALTER Group is also the European market leader for EEE components for high reliability applications.
- The individual ALTER companies will continue operating in their geographical locations within an integrated organisation structure to implement the group synergies.
- Maintain laboratories in UK, Spain, Italy and France.
- Our highly specialised services range from the electronic component evaluation, procurement and acceptance, to equipment certification (EC marking) and electromagnetic compatibility engineering.
- A solid specialised technology base, permanent innovation and quality assured to ISO 9001, more than 189 professionals and revenues in excess in 2006 of 44 M€ are the pillars sustaining our company.

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ALTER TECHNOLOGY GROUP

Alter Introduction continued…

ALTER is an European leading company specialised in the field of part engineering, testing, quality and procurement for Space, Aerospace & Defence and other industrial applications certified to ISO-9000-2000. Our highly specialised service range from the electronic part evaluation, procurement and acceptance, to the equipment certification (EC marking) and electromagnetic compatibility engineering.
A solid specialised technology base, permanent innovation and quality, more than 189 professionals are the pillars sustaining our company.

Tecnologica is based in Seville and Madrid in Spain,was established in 1986. In 1993 the headquarters and laboratories were moved to Seville. Expansion of service portfolio to include the engineering and certification of industrial equipment. Operating in space, defence, telecommunications and industrial markets employing 87 highly trained and qualified staff in Seville and Madrid offices.

IGG, a UK based independent, private company, established in 1978 and dedicated to supporting customers needs in 19 countries. IGG employs 44 highly trained and qualified staff in UK and USA offices, specialists in all types and every aspect of hi-reliability parts. Innovators in the use of all part Quality levels for all applications operating in space, aerospace and defence & industrial markets and a service provider for part users & manufacturers.

Toprel is based in Rome, Italy and was established in 1988, with the main objective of supplying services to space industries in the field of EEE high-reliability parts.
Employing 24 highly qualified staff including part engineers specialised in the field of Hi-Rel parts with large experience in space projects and technical experts in the field of parts testing, semiconductor physics, radiation, failure analysis.

Hirex is based in France, was established in 1993 employs 34 highly skilled and trained engineers and technicians with cumulative expertise in high-reliability space parts, experts in semiconductors physics, parts manufacturing, board and test systems design, technology and device construction, radiation effects and testing, within a new facility of 1700 m².

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Presentation Objective

- Introduce Japanese Space and Aerospace companies to the Alter Group.
- Provide Japanese Space and Aerospace companies with an insight into the capabilities of European parts manufacturers.
- Provide Japanese Space and Aerospace companies with an overview of the European Space Agency (ESA), ESA qualified and preferred component manufacturers (QPL) and ESA qualified parts list (EPPL).

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Introduction to European Space Agency (ESA)

- The European Space Agency (ESA), established in 1974, is an inter-governmental organisation dedicated to the exploration of space, currently with 17 member states. These include France, Germany, UK, Belgium, Spain, Switzerland, Netherlands, Sweden, Austria, Norway, Denmark, Finland, Ireland, Greece, Portugal, Luxembourg Bosnia & Herzegovina.
- ESA headquarters are in Paris, ESA has a staff of about 1,900 with an annual budget of about €2.9 billion in 2007.
- ESA has published and maintains a large number of Quality Standards relevant to the procurement, screening, LAT testing and derating of hi-reliability Space parts, these Standards are adopted where applicable by the ALTER Group.
- ESA also published and maintains a list of ESA Qualified manufacturers (QML), Qualified Parts List (QPL) and a list of European Preferred Parts (EPPL), both publications are applicable to all parties involved at all levels of space segment hardware and it’s interfaces.

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ESA QML

- The ESA QML (REP 006 Issue 1 dated April 2007) contains a list of qualified manufacturers that have been certified by the European Space Agency for technology flows that meet the requirements of the ESCC System. Each technology flow qualification and it's subsequent maintenance is monitored and overseen by the ESCC Executive.
- ESA certifies the manufacturers qualification upon receipt of a formal application from the Executive stating that all applicable ESCC requirements have been met by the pertinent manufacturer. The manufacturers details will then appear in the ESA QML.
- The qualified electronic components produced from the technology flows operated by certified manufacturers are intended for use in ESA and other spacecraft and associated equipment.
- Currently there is only one component manufacturer listed in the QML, Atmel Nantes France.

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ESA QPL

- The ESA QPL (REP 005 Updated 15th Aug 2007) contains a list of components that have been qualified to the rules of the ESCC System and are intended for use in ESA and other spacecraft and associated equipment in accordance with the requirements of ECSS-Q-60 (Space Product Assurance – EEE components).
- Components qualified to the ESCC are grouped together by component type designations within the QPL, derived from industrial standards. These groups are sub-divided into individual component listings including passive components, microcircuits, relays, fuses, transistors, wire & cable etc.
- Component manufacturers details and relevant procurement specifications are also provided within the QPL.

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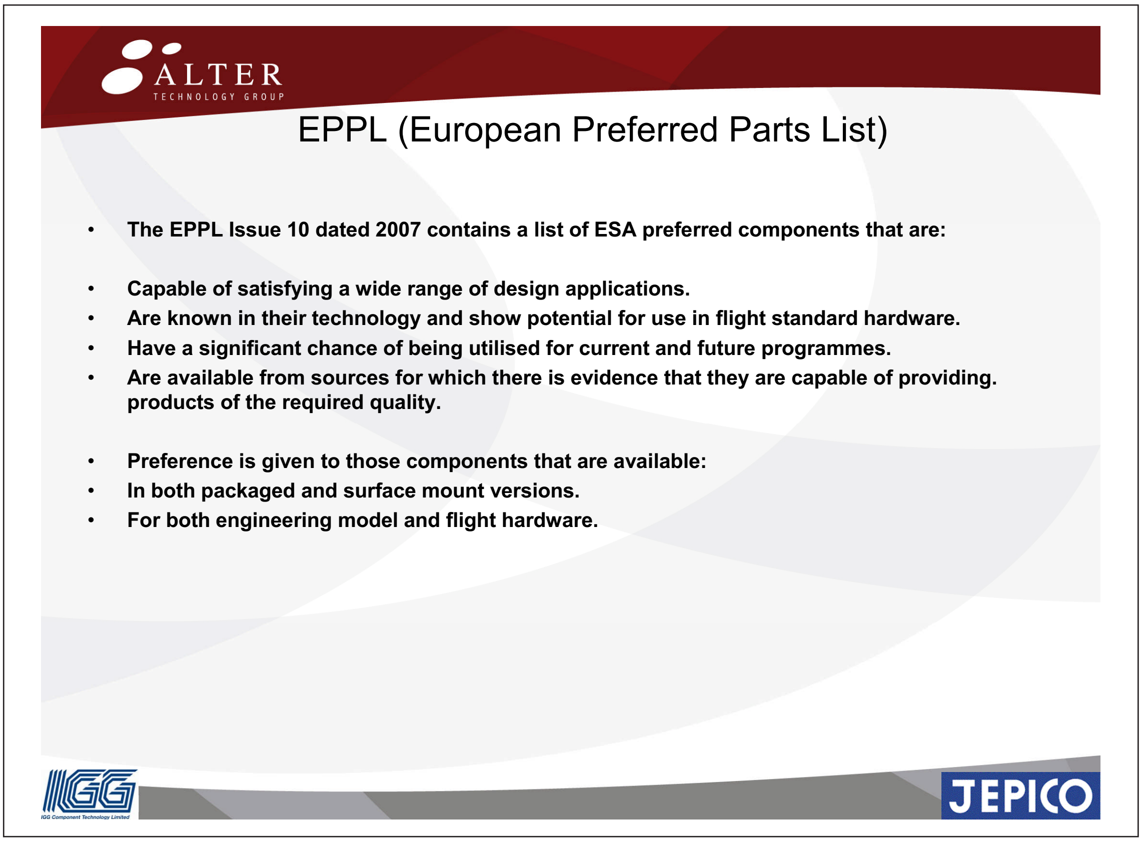
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EPPL (European Preferred Parts List)
• The EPPL Issue 10 dated 2007 contains a list of ESA preferred components that are:
• Capable of satisfying a wide range of design applications.
• Are known in their technology and show potential for use in flight standard hardware.
• Have a significant chance of being utilised for current and future programmes.
• Are available from sources for which there is evidence that they are capable of providing. products of the required quality.
• Preference is given to those components that are available:
• In both packaged and surface mount versions.
• For both engineering model and flight hardware.
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ESA European Preferred Parts Manufacturers:
• EPPL Manufacturers include:
• AVX Ltd,
• Axon Cable,
• Arcotronics,
• ABB Entrelec,
• Atmel,
• Astrium Velizy,
• Analog Devices,
• Betatherm,
• Compagnie,
• C-Mac,
• Chelton Telecom & M/wave,
• Caddock,
• Compeca,
• Deutch,
• Draka,
• Eurofarad,
• Firadec,
• ITT Canon,
• Infineon Technologies,
• Intersil,
• IRCA Division,
• International Rectifier,
• Kemet Electronics Corp,
• Leach International,
• Micro-semi,
• Microspire,
• National Semiconductor,
• Ommic, Radiall,
• Syfer Technologies Ltd,
• Souriau,
• Sensitron,
• ST Microelectronics,
• STPI, State of the Art,
• Texas Instruments,
• Tyco,
• UMS,
• Vishay,
• YSI Temperature,
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European Component Manufacturers with Space Capability

	Company	Presentation Included		Company	Presentation Included		Company	Presentation Included
1	4Link	Yes	19	Glenair	Yes	37	Radiall	Yes
2	ABB Switches		20	Gore		38	Rakon (Was Cmac crystal)	
3	Arcotronics	Yes	21	Hypertac		39	RICA	
4	Atmel	Yes	22	Infineon	Yes	40	Saft	
5	AVX/F		23	ISOcom		41	Schurter (CH)	
6	AVX/IR		24	Jena-Optronik		42	Semelab	Yes
7	Axon Cable		25	KVG(D)		43	Sfernice(Vishay)	Yes
8	Betatherm Measurement Speciality	Yes	26	Leach		44	Souriau	Yes
9	C&K Components (Was Cannon)	Yes	27	MA-COM		45	ST	
10	Chelton CTM	Yes	28	Microspire	Yes	46	STPI	Yes
11	CMAC Microcircuits	Yes	29	MINCO		47	Syfer	
12	Comepa	Yes	30	Nexans		48	Tekdata (Cryoconnect)	Yes
13	Deutsch connector		31	Norspace	Yes	49	Temex Ceramics	Yes
14	Deutsch Relay		32	OMMIC	Yes	50	Trak	Yes
15	Dynex	Yes	33	OSI	Yes	51	Tyco	
16	Eurofarad		34	Oxley		52	UMS	
17	FILCO (Draka-Fileca)		35	PDI		53	Zarlink	Yes
18	Firadec	Yes	36	Peregrine				

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ALTER TECHNOLOGY GROUP

1-Four Links

- **Location: Milton Keynes, England**
  Website: www.4links.co.uk
- **Technology/Product Family: Specialist Test Equipment.**
- **Established: 1976**
- **Qualification: Links are the basis of both IEEE1355 standard and SpaceWire, the standard derived from IEEE1355 for the space industry.**
- **Heritage:Over 30 years in research, development and manufacture of specialist diagnostics and analysis test equipment using SpaceWire technology.**
- **Product Range: SpaceWire test equipment for architectural simulation, test, debug, negative testing, validation, monitoring, measuring operating margins, measuring parameters for modelling, analysing, remote test & debug, remote integration.**

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ALTER TECHNOLOGY GROUP

3-Arcotronics Ltd

- **Location: Towcester, Northants UK**
- **Website: www.arcotronics.ltd.uk**
- **Technology/Product Family: Film Capacitors.**
- **Established: 1954**
- **Qualification: ESA/SCC 3003/005, BSi, IECQ & MiL**
- **Heritage: Involvement in Space and aerospace programs since 1970's.**
- **Product Range: Tantalum, Non-solid, Electrolytic and Fixed Capacitors, EMC/RFI Filters & PFC products.**

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ALTER TECHNOLOGY GROUP

4-Atmel

- **Location: St Quintin-enYvelnes, France**
- **Website: www.atmel.com**
- **Technology/Product Family: Rad Hard Integrated Circuits.**
- **Established: 1985.**
- **Qualification: ISO 9001/TS16949, ISO 14001& ESA QML company.**
- **Heritage: For over 20 years Atmel has been a leading supplier of IC's to the Aerospace industry.**
- **Product Range: Microprocessors, DSP's, Communication IC's, ASIC's & FPGA's**

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ALTER
TECHNOLOGY GROUP

8-Betatherm

- Location: Galway, Ireland UK
  Website: www.betatherm.com
- Technology/Product Family: Designer/manufacturer of sensors and sensor based systems.
- Established: 1990
- Qualification: ISO9001 & 14001, TS16989, AS9100 & ESCC 4006.
- Heritage: Over 25 years experience manufacturing products for space applications.
- Product Range: High temp surface probes, Leaded Discrete & Glass Encapsulated Thermistors, Leadless gold chips.

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ALTER
TECHNOLOGY GROUP

9-C & K Components (Formerly Cannon)

- Location: Dole, France
- Website: www.ck-components.com
- Technology/Product Family: Connectors & E/Mechanical switches
- Established: 30 years +
- Qualification: ISO 9001, ISO TS 16949, ISO 14001, ESA/ESCC 3401 & MIL 24308
- Heritage: Over 30 years supplying connectors to space and aerospace industries.
- Product Range: Connector type MDM, type D Sub & type MTB1

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ALTER TECHNOLOGY GROUP

10-Chelton Telecom & Microwave

- Location: Manufacturing facilities in UK (Chichester) & France (Plaisir, Les Ulis, Gradignan, Goussainville, Les Clayes-sous-Bois).
  Website: www.c-tm.com
- Technology/Product Family: Silicon components for space application.
- Established: 20 years +
- Qualification: ESA ESCC
- Heritage: Over 20 years supplying high-reliability EEE parts to the space & aerospace industry.
- Product Range, High power, fast switching, AGC Attenuator & limiter diodes, Varactors and Mos Caps.

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ALTER TECHNOLOGY GROUP

11-C-MAC Microtechnology

- Location: Great Yarmouth, Norfolk U.K.
- Website: www.cmac.com
- Technology/Product Family: Microelectronic circuits.
- Established: 20 Years +
- Qualification: MIL-PRF-38534, MIL-STD 1553, ISO 17025
- Heritage: Supplier of hybrid electronics to space programmes in USA & Europe for over 20 years.
- Product Range: High reliability electronic systems for harsh and remote environments.

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ALTER TECHNOLOGY GROUP

12-Comepa

- Location: Bagnlet Cedex, France
- Website: www.compeca.com
- Technology/Product Family: Thermostats.
- Established: 20 years +
- Qualification: ESA & CNES
- Heritage: Supplier of thermostats to the aerospace and space industry since 1999.
- Product Range: Bimetallic, SPST Hermetically sealed Thermostats.

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ALTER TECHNOLOGY GROUP

15-Dynex Semiconductor Ltd

- Location: Lincoln, UK
- Website: www.dynexsemi.com
- Technology/Product Family: Power semiconductors and integrated circuit products.
- Established: Established in Lincoln over 50 years ago when it was known as AEI Semiconductors Ltd.
- Qualification: ISO 9001/2000 & 14001/2004
- Heritage: Dynex Semiconductor is a global supplier of products and services specialising in the field of power semiconductors and integrated circuit products. The Company's power products are used to improve the efficiency, reliability and quality of the electric power in;

  Power transmission and distribution, alternative power generation, marine and rail propulsion, aerospace, medical equipment, heavy industries such as steel and mining, telecommunications and electric vehicles.
- Product Range: Power Semiconductors, SOS circuits & SAW Filters.

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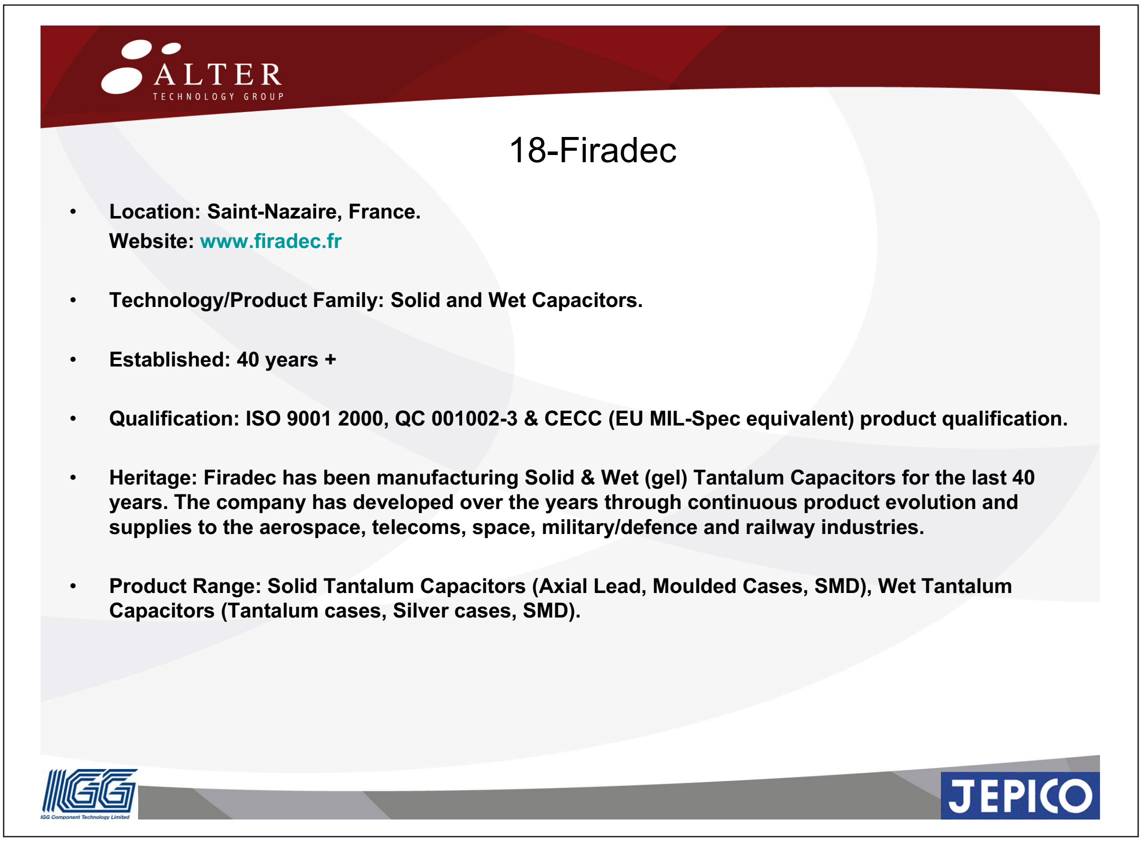
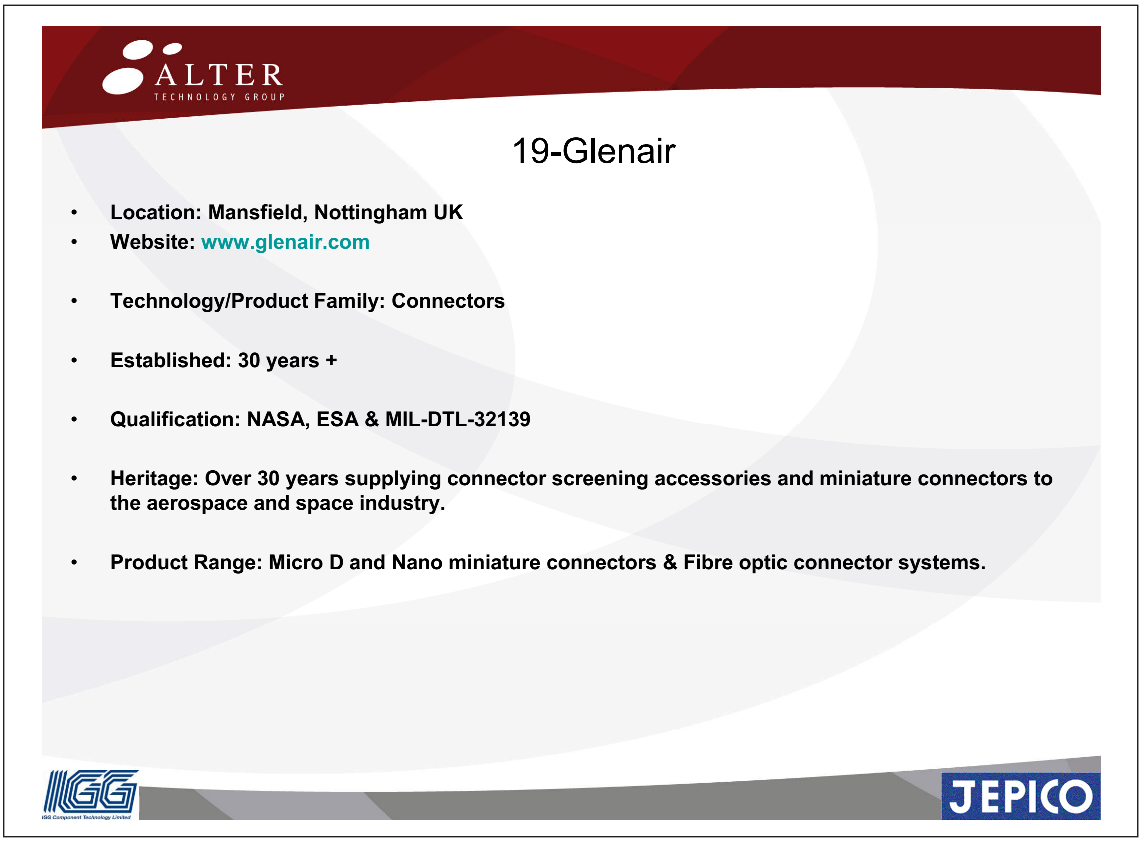

ALTER
TECHNOLOGY GROUP
18-Firadec
• Location: Saint-Nazaire, France.
Website: www.firadec.fr
• Technology/Product Family: Solid and Wet Capacitors.
• Established: 40 years +
• Qualification: ISO 9001 2000, QC 001002-3 & CECC (EU MIL-Spec equivalent) product qualification.
• Heritage: Firadec has been manufacturing Solid & Wet (gel) Tantalum Capacitors for the last 40 years. The company has developed over the years through continuous product evolution and supplies to the aerospace, telecoms, space, military/defence and railway industries.
• Product Range: Solid Tantalum Capacitors (Axial Lead, Moulded Cases, SMD), Wet Tantalum Capacitors (Tantalum cases, Silver cases, SMD).
JEPICO


ALTER
TECHNOLOGY GROUP
19-Glenair
• Location: Mansfield, Nottingham UK
• Website: www.glenair.com
• Technology/Product Family: Connectors
• Established: 30 years +
• Qualification: NASA, ESA & MIL-DTL-32139
• Heritage: Over 30 years supplying connector screening accessories and miniature connectors to the aerospace and space industry.
• Product Range: Micro D and Nano miniature connectors & Fibre optic connector systems.
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ALTER TECHNOLOGY GROUP

22-Infineon Technologies

- Location: Dresden, Germany.
- Website: www.infineon.com
- Technology/Product Family: High rel discrete and microwave semiconductors & transistors.
- Established: 35 years +
- Qualification: ESA & MIL Std
- Heritage: Supplying high-rel components to the space industry for over 35years.
- Product Range: Silicon diodes & transistors for various applications.

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ALTER TECHNOLOGY GROUP

28-Microspire

- Location: Lllange, France
- Website: www.microspire.com
- Technology/Product Family: Wound Magnetics
- Established: 1978
- Qualification: ISO 900/V2000 & EN9100, ISO 14001 in progress.
- Heritage: Over 30 years supplying wound products to the aerospace industry and over 15 years supplying wound products to the space industry.
- Product Range: Chip Inductors, SESI Technology, Encapsulated Wound Magnetics, Linear Windings, Motor Windings & Chokes. Gate Drive, V & I Measurement & Bus Transformers.

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ALTER TECHNOLOGY GROUP

31-Norspace

- Location: Horten, Norway
- Website: www.norspace.no
- Technology/Product Family: Complex analog signal processing equipment and components for satellite payloads.
- Established: 1984
- Qualification: ISO 9001/2000
- Heritage: Supplier of electronic components and equipment to the space industry for over 20 years.
- Product Range: Analog signal processors, frequency Generators & Converters, Telemetry, Tracking & Command units, Interconnect Processors, SAW Filters & hybrid components.

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ALTER TECHNOLOGY GROUP

32-OMMIC

- Location: Limeil-Brévannes Cedex, France
- Website: www.ommic.com.
- Technology/Product Family: MMIC circuits & Epitaxial Wafers based on III-V (GaAs and InP) materials.
- Established: 1972
- Qualification: ISO 9001:2000 & ISO 14001:2004
- Heritage: 30 years of background in materials, design and processing.
- Product Range: Ultra Low Noise Amplifiers with high IP3 for Base Stations, Wide Band Amplifiers for Instrumentation and Defence, Millimetre Wave Low Noise Amplifiers, Control Functions (Attenuators, Phase Shifters and Integrated Core Chips) and Interface Circuits for High Speed Optical Fibre Systems.

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ALTER TECHNOLOGY GROUP

33-OSI Optoelectronics AS

- Location: Horten, Norway
  Website: www.udt.com
- Technology/Product Family: Optoelectonic components and Subsystems
- Established: 1967
- Qualification: MIL-I-45208 (DOD Certification), MIL-PRF19500 Quality System Compliance), MIL-TD-883 & MIL-STD-750 Compliance, J-STD-001C qualified Soldering Instructor), AQAP – 110 approved for traceability, materials & processes.
- Heritage: Over 40 years in designing & manufacturing Optoelectonic Components & Subsystems.
- Product Range: Photo-Diodes (X-Ray, UV, Visible, NIR) Photo-Transistors, Photo-Reflectors, LED Assemblies, VCSEL Assemblies, Optical Switches, Opto Couplers, Opto Interrupters, Receivers, Transmitters, Hybrids, Thick/Thin Film Ceramic, Optical Assemblies, Opto-Mechanical Assemblies, Electro-Mechanical Assembies & PCB Assemblies.

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ALTER TECHNOLOGY GROUP

37-Radiall

- Location: Rosny Sous Bois, France
- Website: www.radiall.com
- Technology/Product Family: Coaxial cables & connectors, Semi rigid cables.
- Established: 1974
- Qualification: ESA/ESCC 3402, CNES and MIL qualifications.
- Heritage: Radiall have been supplying cables to the space industry for over 30 years, over 160 satellites have been built with Radiall cables.
- Product Range: Coaxial Connectors, Low loss cable assemblies, Semi-rigid cables. Coaxial terminations, attenuators, couplers, switches & phase shifters.

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TECHNOLOGY GROUP

42-Semelab

- Location: Scotland
  Website: www.semelab.com
- Technology/Product Family: Discrete Semiconductors, Linear IC's, Hybrids, Sensors and ASIC's.
- Established: 35 years +
- Qualification: ESA 5000/9000, MIL-STD 38535 (DSCC-VQC-03-003049 & DSCC-VQC-03-003050) Processed parts in accordance with MIL-PRF19500, BS9001& CECC.
- Heritage: For over 35 years has been growing it's customer base to supply the worlds leading defence, space and medical markets worldwide.
- Product Range specific for space market include: Solarfet EU source for full Radiation Tolerant Mosfets, Power Bipolar, Small signal Bipolar, Jfet's, Small signal diodes, RF Mosfet's.
- Latest technology includes: Extended range of Rad Tol Mosfet's, 1000V Rad tol Bipolar, RF Mosfet's 3 watt – 400 watt 1.5GHz, Glass/Ceramic free ultra low weight Silicon Nitride Hybrids, Lightweight Ceramic To257 packages, Hermetic Melf diodes to space level.

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ALTER
TECHNOLOGY GROUP

43-Sfernice / Vishay

- Location: Selb, Germany
  Website: www.vishay.com
- Technology/Product Family: High rel discrete semiconductors and passive electronic devices.
- Established: 1970
- Qualification: ESCC 4001(023, 026 & 025).
- Heritage: Vishay/Sfernice has been supplying semiconductors and passive electronic components to the space industry for over 35 years.
- Product Range: Thin film Chip Resistors,Thick film Chip Resistors, Thin film Chip Arrays, Bare Chips & Bare Networks.

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ALTER TECHNOLOGY GROUP

44-Souriau

- **Location: Dunstable (UK), Stockholm (Sweden), Wuppertal (Germany) Marolles-en-Brie (France), Turino (Italy).**
  Website: www.souriau.com
- **Technology/Product Family: Connectors**
- **Established: 1917**
- **Qualification: ISO 9001/ISO 14001 MIL-STD 790 NATO AQAP 2110 BOEING D1-9000/ AS-9100**
- **Heritage: The company has been manufacturing connectors for nearly a century. Souriau is now a leading connector manufacturer dedicated to the industrial, military and aerospace markets and specialists in extreme environment connectors.**
- **Product Range: Signal, Power, Coaxial, Fibre optic, ethernet and high temperature connectors.**

IGG Component Technology Limited JEPICO

ALTER TECHNOLOGY GROUP

46-STPI

- **Location: Paris, France**
- **Website: www.stpi.net**
- **Technology/Product Family: Switching technology for severe environments.**
- **Established: 1955.**
- **Qualification: ESA/ESCC, ISO 90012000, AQAP 2110, AS/EN/JISQ 9100 & MIL Std 790**
- **Heritage: Suppliers of switching technology components to the aerospace & defence industry and railways for over 50 years and space industry for over 10 years.**
- **Product Range: Hermetically sealed, Time Delay, Latching & Non-latching, Static Contactors.**

IGG Component Technology Limited JEPICO

ALTER TECHNOLOGY GROUP

48-Tekdata Cryoconnect

- **Location: Staffordshire UK.**
  Website: www.cryoconnect.co.uk
- **Technology/Product Family: Cables & Connectors.**
- **Established: 20 years +**
- **Qualification: ISO 9001/2000, ECSS-Q20 & ECSS-Q-70.**
- **Heritage: Over the past 20 years Tekdata has become exclusive set of companies able to meet NASA's demanding specifications for space-borne interconnection systems. The company supplies the autosport and pleasure craft, space, cryogenic, avionics, marine, medical and instrumentation markets with high specification competitively priced wiring systems.**

IGG Component Technology Limited JEPICO

ALTER TECHNOLOGY GROUP

49-Temex Ceramics

- **Location: Pessac, France**
- **Website: www.temex-ceramics.com**
- **Technology/Product Family: Single and Multi-layer Capacitors**
- **Established: 1971**
- **Qualification: ISO 9001/2000 & ISO 14001/2000**
- **Heritage: Temex-Ceramics started its activities in 1971 in Pessac with the manufacturing of trimmer capacitor, tuning elements and ceramic multilayer capacitors. For the past 35 years, Temex-Ceramics has consolidated and strengthened its position as market leader, in Ceramic multilayer Capacitors, Air, Ceramic Sapphire dielectric trimmer capacitors and tuning elements for cavity filters, Ferrite & dielectric resonators.**
- **Product Range: High power/high voltage capacitors, Trimmer capacitors, Frequency tuning Elements, Air trimmer capacitors, Ferrite materials & power loads.**

IGG Component Technology Limited JEPICO

50-TRAK

- Location: Dundee UK
  Website: www.trak.com
- Technology/Product Family: Microwave products.
- Established:1960
- Qualification: ISO 9001:2000, AS9100:2004, MIL-PRF-38534, ANSI/J-STD-001, NASA-STD-8739.3, DOD Internal Security & IPC Manufacturing Quality Standard.
- Heritage:TRAK Microwave is a world class supplier of high reliability microwave & RF sub-systems and components to global satellite market.
- Product Range: Passive space products including: Waveguides, Isolators & Circulators, Loads & Terminations, Waveguide Switches, Coaxial connectors & multi-junctions, Circulator & Isolators, Combiners & MICPuck's.

53-Zarlink

- Location: Zarlink has R&D centers in Ottawa; San Diego, Phoenix, Austin and Reading (U.S.A.); Jarfalla (Sweden); and Caldicot, Swindon and Plymouth (UK).
- Website: www.zarlink.com
- Technology/Product Family: Semiconductors
- Established: 30 years +
- Qualification: ISO 9001/2000
- Heritage: For over 30 years, Zarlink has delivered semiconductor solutions that drive the capabilities of voice, enterprise, broadband and wireless communications. Customers include Cisco, Alcatel-Lucent, Nortel, Huawei, ZTE, Given Imaging, Cochlear, Nokia Siemens Networks and Ericsson.
- Product Range: Timing and synchronization ICs for telephony VoIP solutions; telecom networking ICs; ultra low-power ICs for healthcare; voice echo cancellation; optical modules for switching, routing and data center applications.

ALTER TECHNOLOGY GROUP

Contacts

REPRESENTED BY

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SHINJUKU-KU, TOKYO 163-0729, JAPAN
Tel: +81-3-3348-0611 Fax: +81-3-3348-0623
Website: www.jepico.co.jp
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IGG Component Technology Limited

IGG Component Technology Limited
Waterside House, Waterside Gardens, Fareham, Hampshire PO
Tel: +44 (0)1329 223500 Fax: +44 (0) 1329 829312
Website: www.igg.co.uk
E-mail: geoff.penhaligon@igg.co.uk

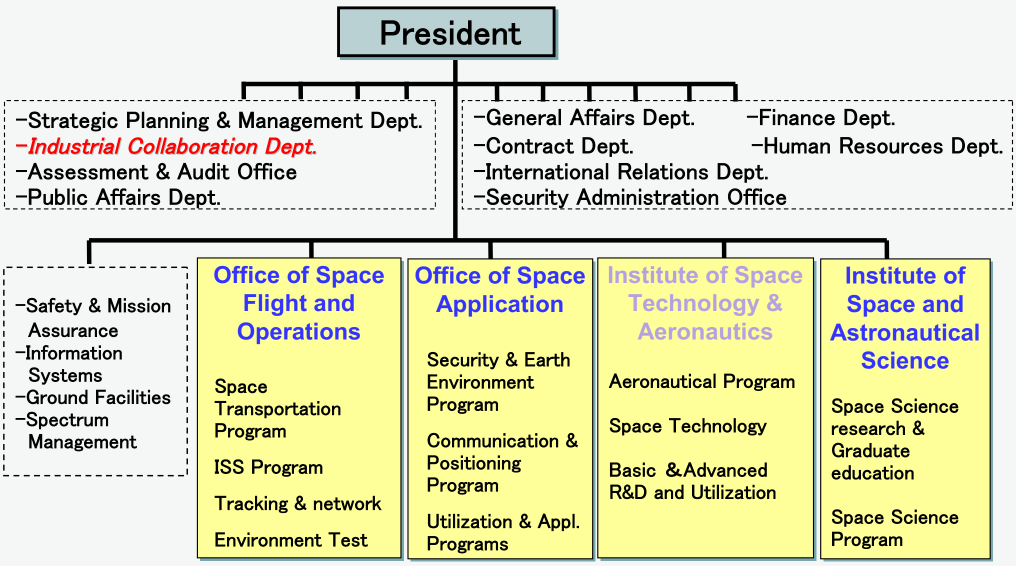
Overview of JAXA Industrial Collaboration Activities

Industrial Collaboration Dept.
JAXA

29/10/2007

1

Organization



JAXA Long-Term Vision

1.Contribute to building a secure and prosperous society through the utilization of aerospace technologies

2. Contribute to advancing our knowledge of the universe and broadening the horizon of human activity

3. Develop the capability to carry out autonomous space activities through the best technologies in the world

4. Facilitate growth of the space industry with self-sustenance and world class capability

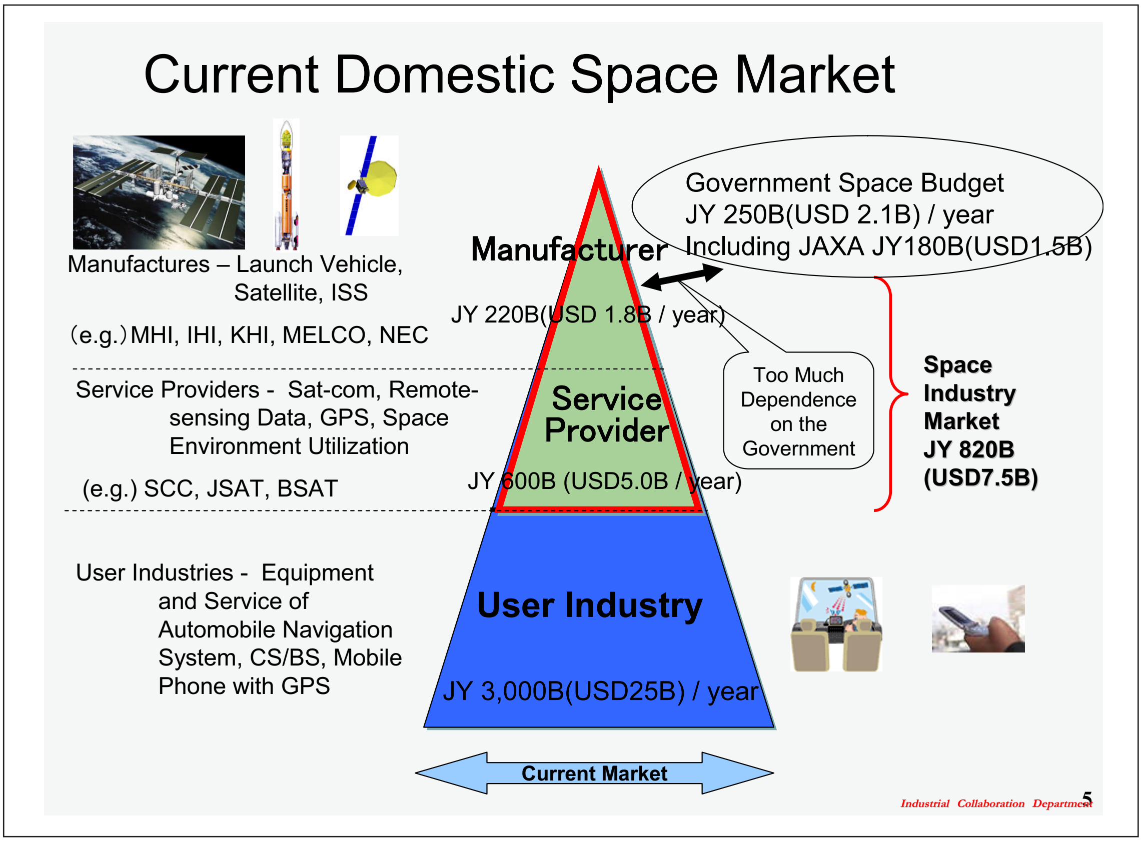
5. Facilitate growth of the aviation industry and aim for technological breakthrough for future air transportation

Collaboration With Industry

For over three decades, Japan has been trying to develop the advanced space technology and to catch up the U.S. and Europe.

While the technological level of space systems has almost reached that of the U.S. and Europe in some major areas, we still have some problems as follows;

- **Japanese space equipment industry heavily depends on the national space budget, mainly R&D budget.**
- **Domestic space utilization market is not well developed and diversified enough for the industry to survive in the market in addition to the government R&D contracts.**
- **Competitiveness of Japanese space manufacturing industry is supposed to remain premature in the international commercial market of launching services and satellites.**

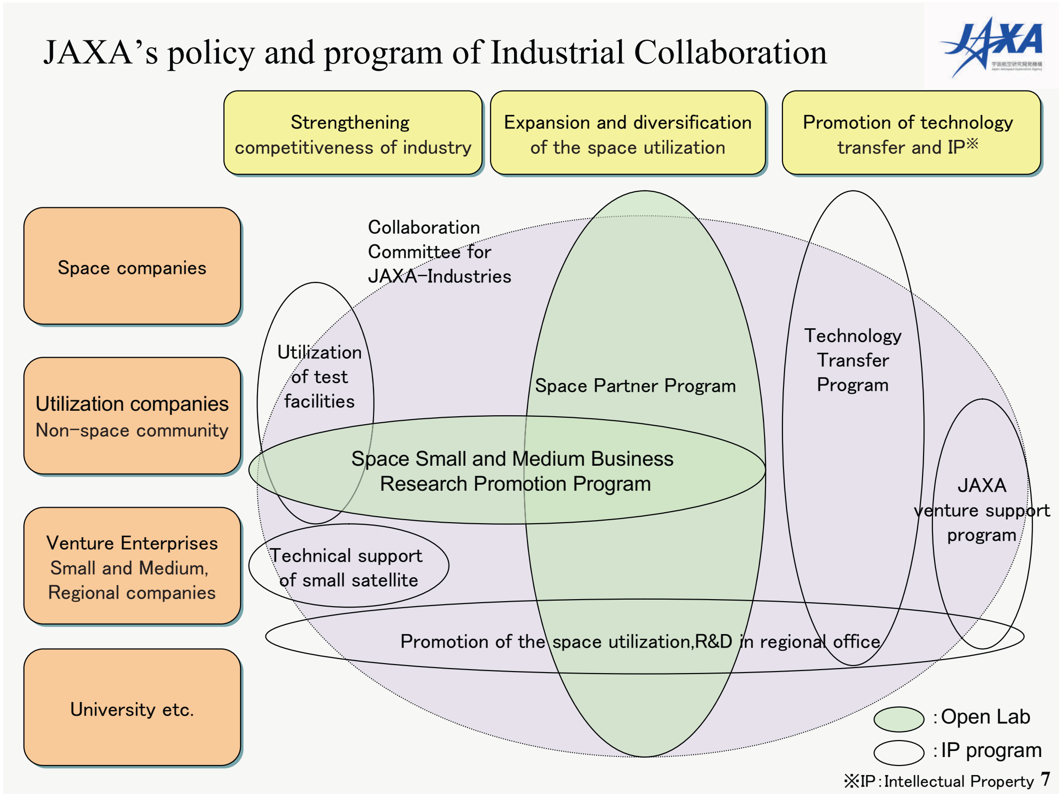


Our Three Objectives

Industrial Collaboration Dept.

1. Contribute to strengthening competitiveness of the Japanese space industry in the international commercial market
2. Promote expansion and diversification of the space utilization market by facilitating participation and penetration into the space activity for people in non-space community and by helping them incubate space ventures.
3. Promote technology transfer to non-space industries with our IPs, the outcome of JAXA's R&D activities in the past

Industrial Collaboration Department 6



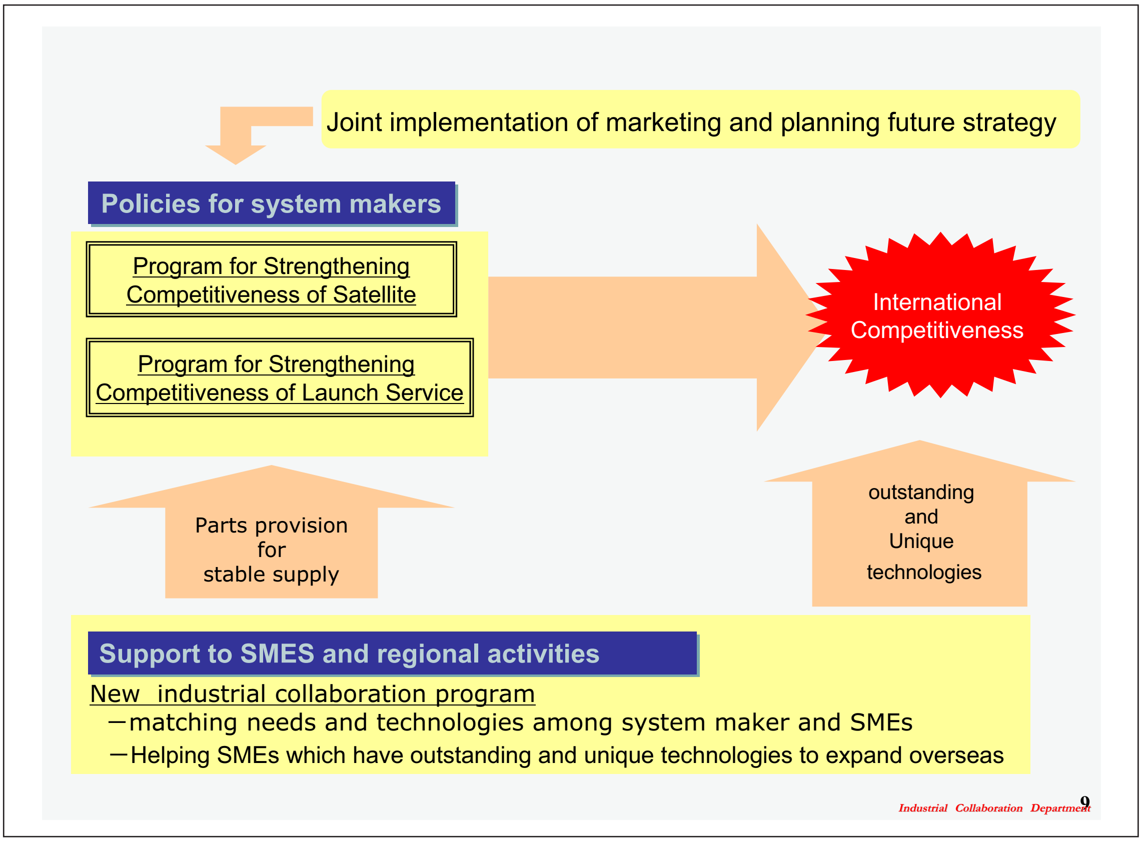
Strengthen Competitiveness

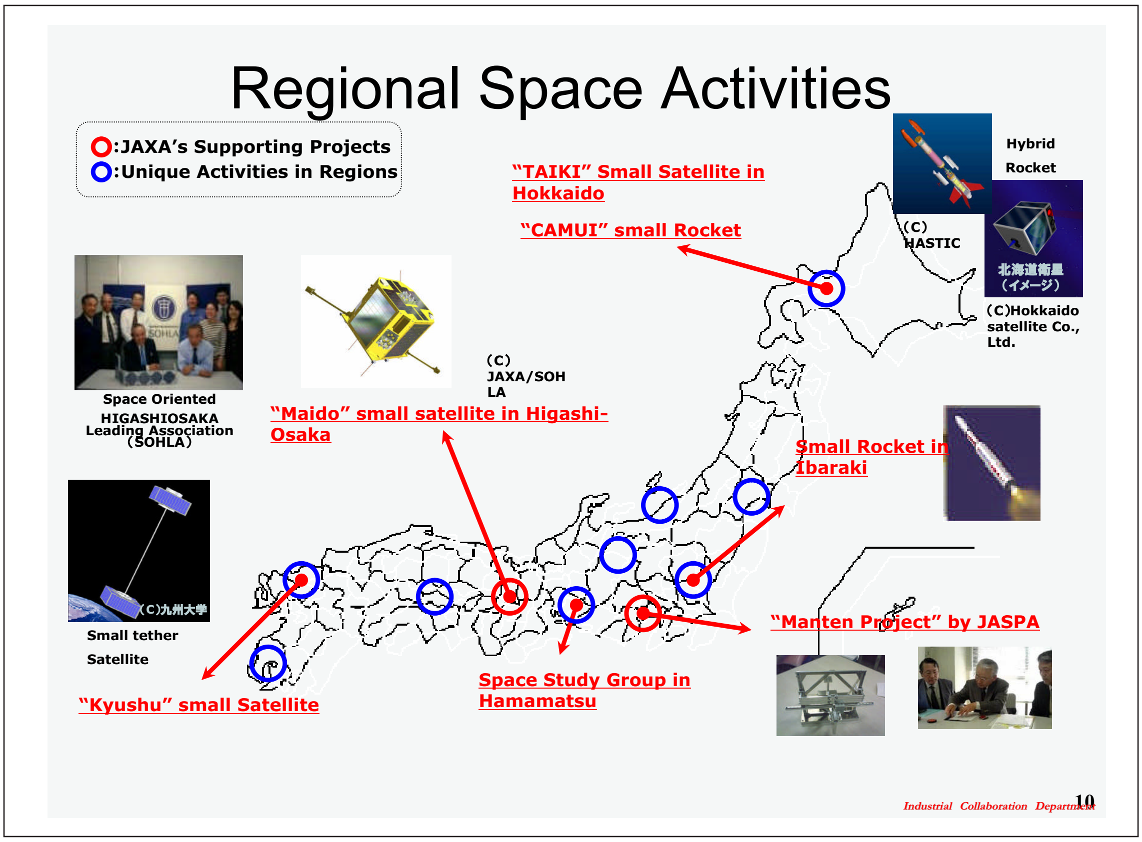
1) For more dialogue with the industry, JAXA holds the collaboration committee with industry to share the goal of fostering market competitiveness.

2) JAXA promotes a variety of supports and measures for the industry such as;

- Standardization
- Technology transfer to the industry
- Technological support to regional small & medium enterprises in East-Osaka which develops small size satellite
- Launch service for small satellites of SMEs and universities with H-IIA surplus capacity (Ainori-project)
- Promote use of JAXA's test facilities by commercial users, providing the timely and appropriate information

Industrial Collaboration Department 8


Joint implementation of marketing and planning future strategy
Policies for system makers
Program for Strengthening Competitiveness of Satellite
Program for Strengthening Competitiveness of Launch Service
International Competitiveness
Parts provision for stable supply
outstanding and Unique technologies
Support to SMES and regional activities
New industrial collaboration program
－matching needs and technologies among system maker and SMEs
－Helping SMEs which have outstanding and unique technologies to expand overseas
Industrial Collaboration Department
9


Regional Space Activities
:JAXA's Supporting Projects
:Unique Activities in Regions
"TAIKI" Small Satellite in Hokkaido
"CAMUI" small Rocket
Hybrid Rocket
(C) HASTIC
北海道衛星（イメージ）
(C)Hokkaido satellite Co., Ltd.
Space Oriented HIGASHIOSAKA Leading Association (SOHLA)
(C) JAXA/SOHLA
"Maido" small satellite in Higashi-Osaka
Small Rocket in Ibaraki
(C)九州大学
Small tether Satellite
"Kyushu" small Satellite
Space Study Group in Hamamatsu
"Manten Project" by JASPA
Industrial Collaboration Department
10

Helping SMEs to expand overseas

- To provide SMEs opportunities to enter the international market, JAXA holds exhibitions and ensures areas in a major exhibition in which Japanese SMEs exhibit samples of parts and products they wish to procure from foreign system maker.

Provide opportunities to exhibit such as ;
1) JAXA booth in "Paris Air Show" (June. 2007)
2) "MEWS 20" held by JAXA (October. 2007)
3) "Japan Aerospace 2008" held by SJAC in yokohama (October. 2008)
4) Parts Exhibition in Europe held by JAXA (to be determined)

Industrial Collaboration Department 11

Promote Utilization

1) To facilitate access to space activities and to increase a number of players especially from non-space community and nurture promising projects in the future, JAXA has a program of realizing easy-access to the space with "Space Open Lab" .

2) As a drastic increase in the space budget is hardly expected in coming several years, a new business model with private initiation and capital infusion from a private sector may be one of the possible ways making a breakthrough in the space industry.

3) As a regional office, Kansai Satellite Office is to contribute to regional economic prosperity and to create new business by encouraging advanced R&D taking advantage of local specialties.

4) JAXA fosters marketing activity to promote commercial application in telecommunication and navigation (ETS-Ⅷ, WINDS), earth observation (ALOS) and space environment utilization (JEM)

Industrial Collaboration Department 12

Space Open Lab: You+JAXA+SPACE =?

あなた ＋ JAXA ＋ 宇宙 ＝ ？
2004年6月スタート
見上げる宇宙から使う宇宙へ

Virtual Lab. on website: easy access to space business
People with various background, know-how, idea and JAXA together create unique space business
JAXA's coordination & technological advice, and budgetary support if selected.

Space Open Lab — Space Partner System / Space Venture System

Space Partner

Discussion →Team making ("Unit") →Detail Research →Business or JAXA Project

On line registration → Step2 Discussion on web → Step3 Unit targeting space business → Step4 Detail study → Step5 Research proposal &selection → Step6 Research → Step7 Business or JAXA project

Coordination (Step2); Technical advice (Step4); Budgetary support（up to ¥30M／year）(Step6)

Space Venture

Frontier theme →proposal for solution →Business or JAXA Project

Step1 On line registration → Step2 Proposal for Frontier theme → Step3 selection → Step4 Detail study → Step5 Business JAXA project

Technical advice (Step2); Budgetary support（up to ¥30M／year）(Step4)

Industrial Collaboration Department 13

Promote Technology Transfer "SPIN-OFF"

JAXA has made efforts to increase a number of the intellectual property and to promote transfer of the space-born technology to the non-space field as Spin Off, which would change our life and society.

A lot of Spin-Offs have been born in the various fields.

- Life
- Environmental improvement
- Medical welfare
- Social infrastructure

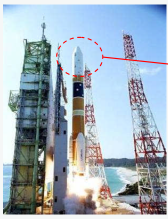
Industrial Collaboration Department 14

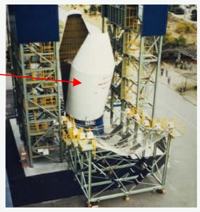
Recent Spin-Off cases at JAXA

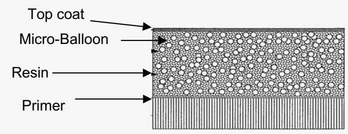
Thermal insulation material

The insulating material for the fairing of H-II Launch Vehicle , which is a type of coating, is so cohesive (that other adhesive materials are not required) ,and also, it can harden at a room temperature (there is no need for extra hardening equipment). As it has a high resistance to deformation, bending, high or low temperature and shock damage, it will neither crack nor become detached. Furthermore, this thermal insulation material is light and has a high performance level for heat.

The thermal insulation technology has already been commercialized and marketed as a heat insulator for buildings.
Developments have moved forward to apply the heat insulating technology to a range of diversified purposes.







発表資料

ワークショップ 2日目

平成19年10月30日（火）

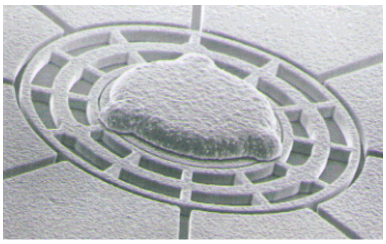
Potential of MEMS for space applications

Institute of Space and Astronautical Science (ISAS),
the Japan Aerospace Exploration Agency (JAXA)
Makoto Mita

What is MEMS?

- MEMS = Micro Electro-Mechanical Systems
- Very small machine, Micro machine
- range in size from a micro to a centimeter
- combines mechanical and electrical structures

It is called “Micromachine” in Japan



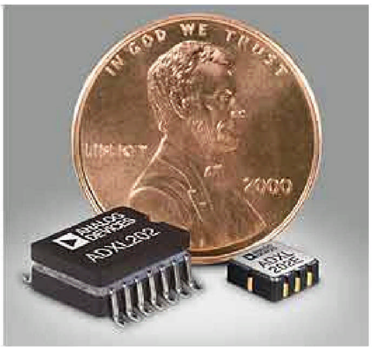
Advantage of MEMS

- Small size and light weight
- Robust for the vibration and the shock of launch due to small mass
- Robust for radiation

MEMS in your life

- Head of ink jet printer
- DLP (Digital Light Processing) : in projector
- Accelerometer, gyroscope
  - In cars, digital cameras, game machines, cellular phone
- Pressure sensor
- Optical scanner
- And so much more …

Market in Japan: several hundreds billion yen
In the future, it will expand to several trillion yen



Coming soon

- MEMS microphone (Si microphone)
- RF switch
- Oscillator
  - SiTime, Discera

Promising space application

- Inertial sensor
  - accelerometer, gyroscope
- High frequency (RF)applications
- Optical sensor, mirror
- Etc..

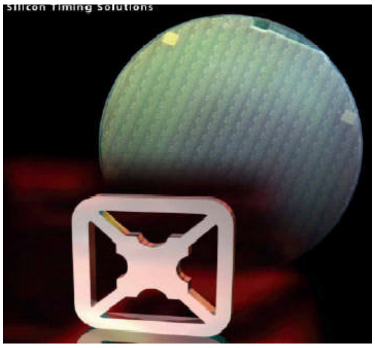
I will mention RF device and inertia sensor next.

RF(Radio Frequency) applications

- High stable oscillator
  - For High precision measurement of distance and high quality communication
  - Ultra stable MEMS oscillator can be alternative to the quartz type USO (Ultra-Stable Oscillator)
- RF switch
  - Low loss, Low impedance
  - For phase shifter, TX-RX switch

MEMS Oscillator

- Alternative quartz oscillator
- The structure does not depend on the crystal orientation
- Smaller than the quartz oscillator with the same performance.
- Suitable for mass production



Possibility of MEMS OSC for space application

- If MEMS USO is realized, it can be alternative quartz type USO.
  - Deep space mission
  - rover
- The vibrator is robust for radiation due to mechanical structure. However control circuit is not robust.

Reliability, stability and downsizing are required.

MEMS RF switch application

- TX-RX switching
- Phase shifter of phased array antenna

Features of MEMS RF switch

Disadvantages
- Slow switching speed (~1MHz)
- A few experiences
- Low reliability (recently, improved)

Advantages
- Low loss @ high frequency
- High ON-OFF contrast
- The performance does not depend on frequency

MEMS RF switch has more advantages at very high frequency (>10GHz) than others

Possibility of MEMS RF SW for space applications

- Smaller phase-shifter
- Robust for vibration and shock due to small size
- High robustness for radiation

RF switch is promising device for the space application

Inertia sensor

Requirements

- High stability
- High sensitivity

Applications

- Attitude control of the satellites and rover
- ION thruster acceleration measurement
- Moonquake observation
- Gravity measurement of small planets

MEMS accelerometer

- It can use attitude measurement of the rovers and the small explorers
- Poor performance for scientific observation and precise attitude control for the satellite

Gyroscope

- Poor performance for scientific observation and precise attitude control for the satellite
  - High Stability < 0.1 deg/h
  - High sensitivity <0.1 deg/h
- It can use attitude measurement of the rovers and the small explorers

MEMS in JAXA

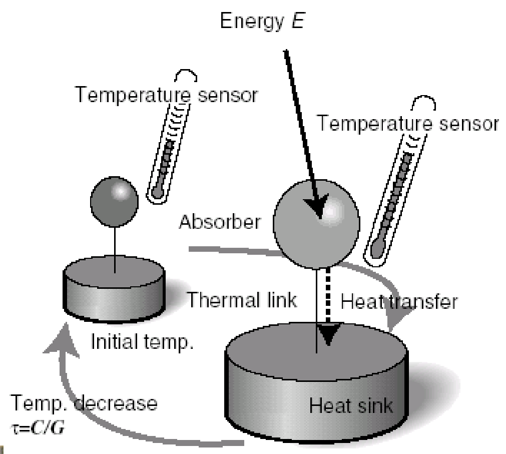
Some MEMS devices under study in JAXA

X-ray observation

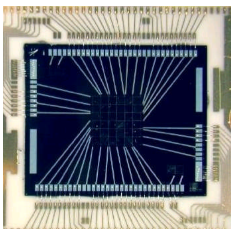
Highly sensitive X-ray detector for X-ray astronomy

X-ray detector

- Temperature of the absorber is elevated by the impinging X-ray, which could be quantitatively measured in terms of the temperature.
- X-ray detector with PN junction temperature sensor is being used for SUZAKU (ASTRO-E2)



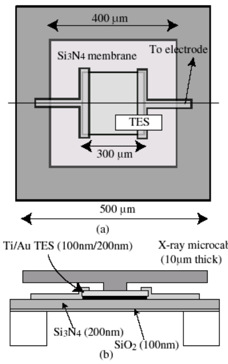
principle



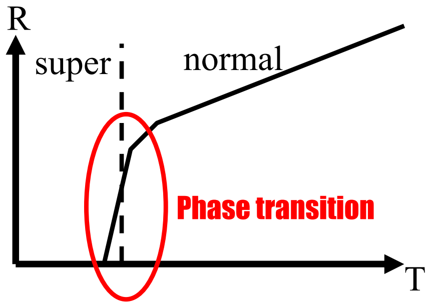
X-ray detector of SUZAKU

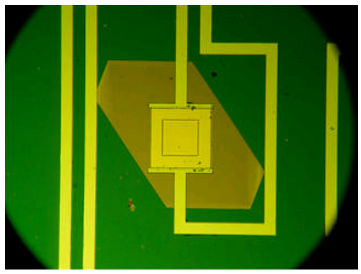
X-ray micro calorimeter

- Phase transition between super conductor and normal conductor is used to detect temperature.



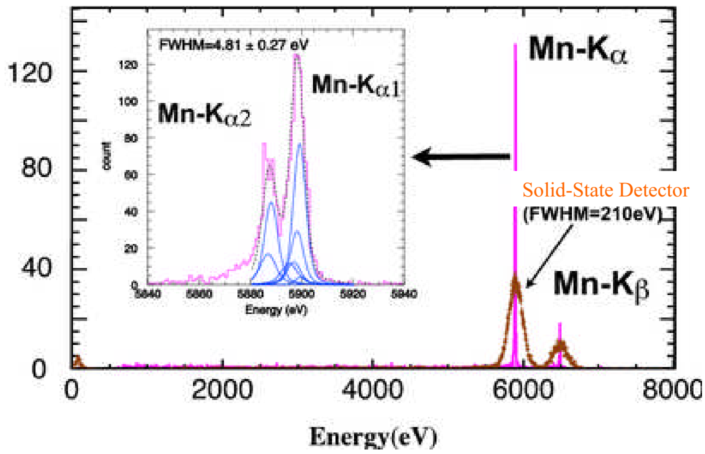
Structure





Photograph

Result



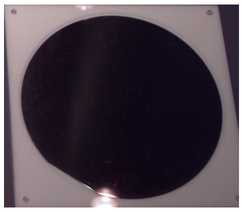
- Energy resolution : 4.81 eV (World record)

X-ray optics

- Dioptric system can not be used for X-ray
- To reduce the size and weight of the X-ray optics, micro pore optics has been developed

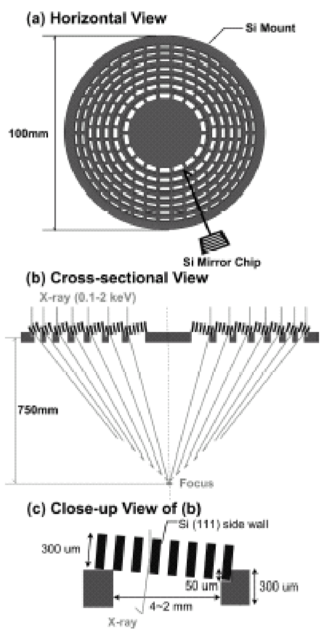
Ezoe et al. 2005 SPIE, PATPEND

MEMS technology →

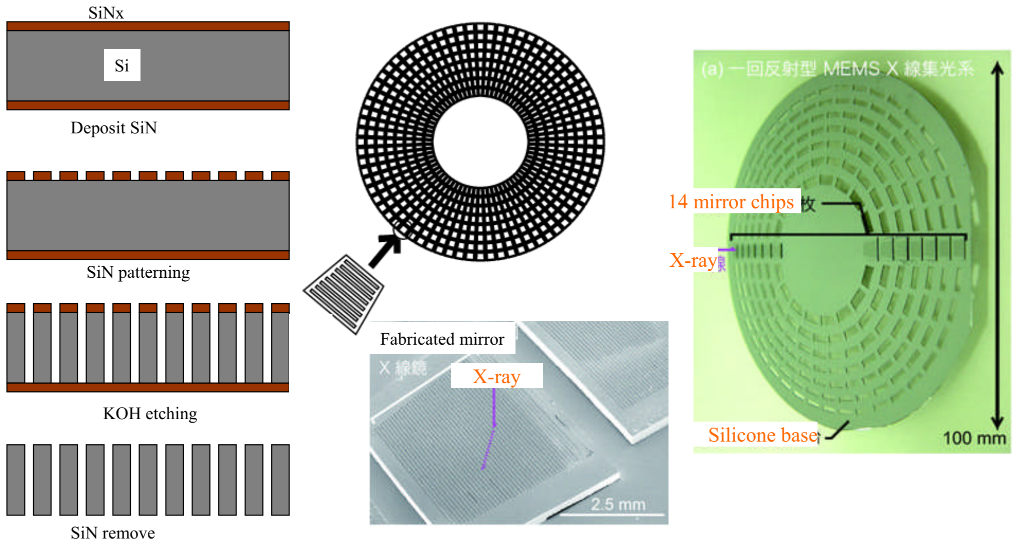


Structure of the MEMS X-ray mirror

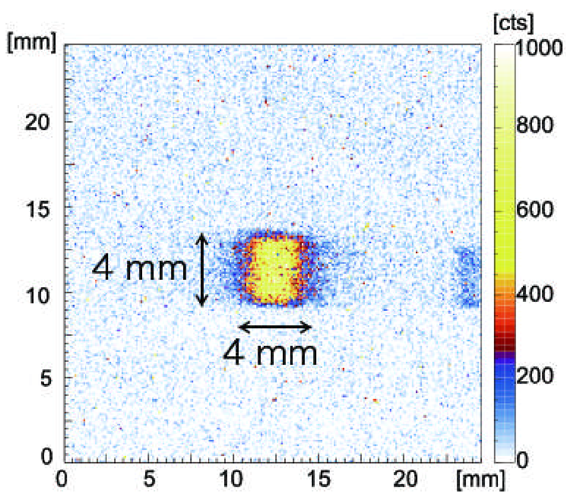
- The structure consists of tiny MEMS mirrors
- Downsizing of whole structure due to small mirror size and the space
- The silicon surface must be smooth



Fabrication and results



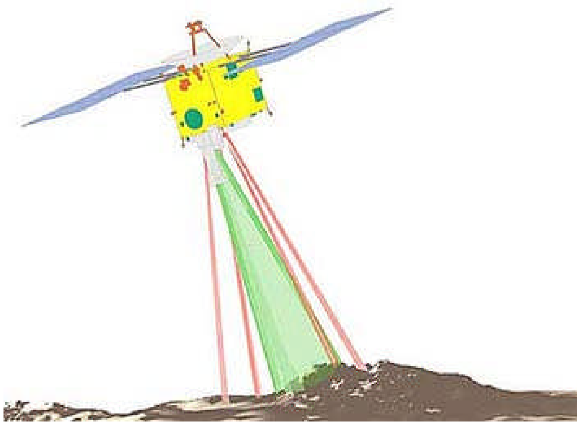
Reflection result



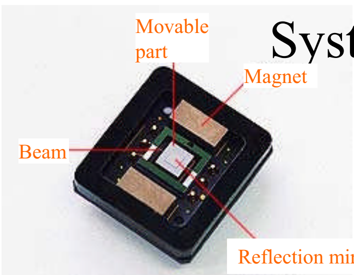
- X-ray reflection was observed by using this MEMS mirror

Landing laser radar

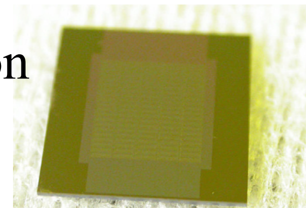
Two-dimensional Scanning Light Detection and Ranging (2D LIDAR) for altimeter on satellite .



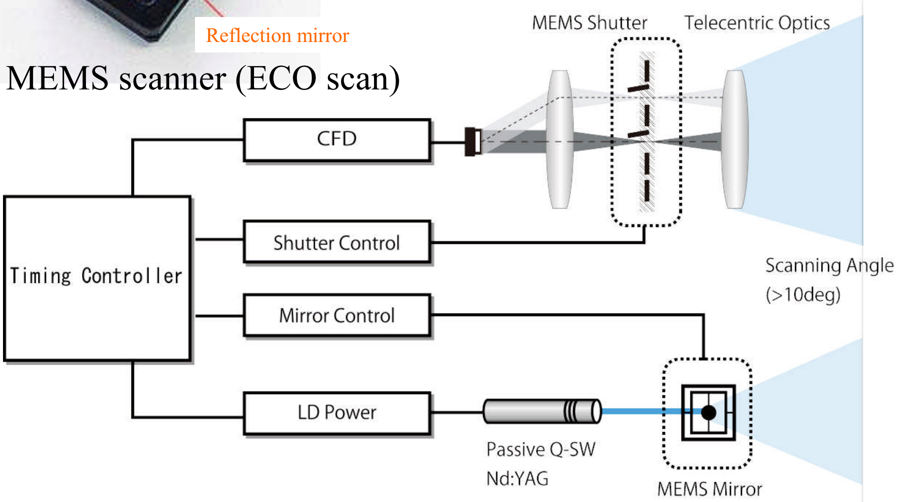
System Configuration



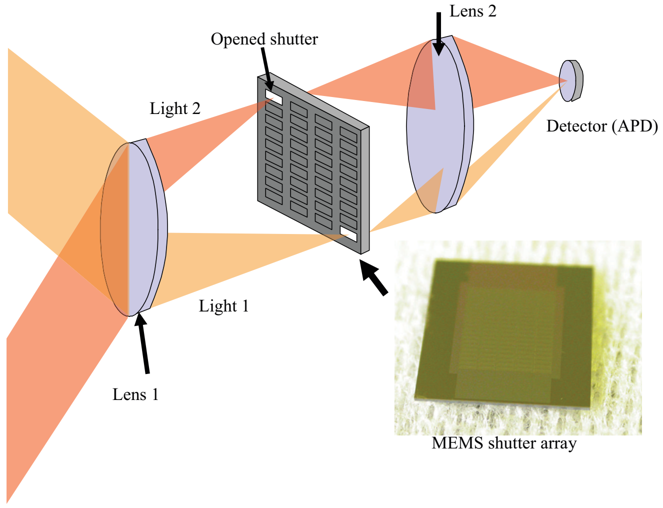
MEMS scanner (ECO scan)



MEMS shutter



Receiver configuration



Micro actuators

Actuators Everywhere

- On small planet
- In small rover/satellite
- Alternative of electrical motor

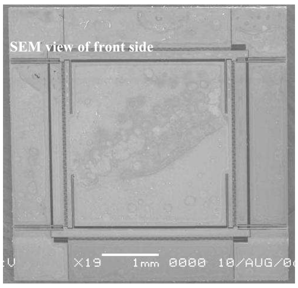
For micro rover and explorer

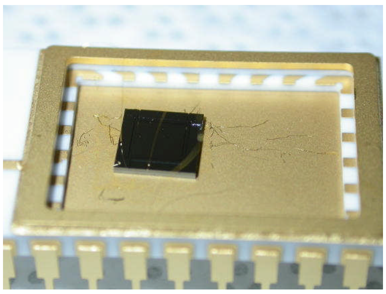
- Gravity of planet is negligible.
- Weight of micro rover is very small
- Wheels are not efficient for maneuvering.
- In these case, inertia drive instead is useful for small planets explorer and small rover.

MINERVA

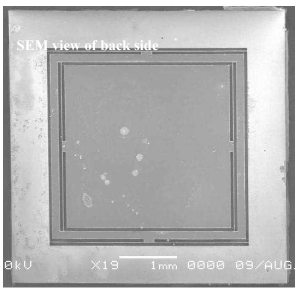
Impact Actuator

- Inertia-driven actuator
- Potential for micro/nano rover maneuvers

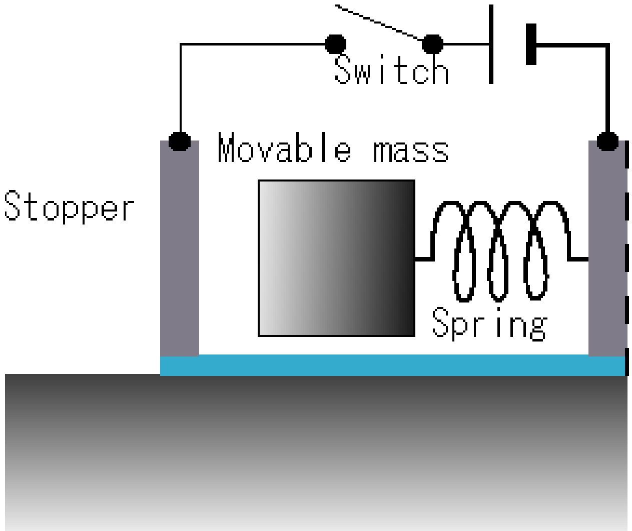




Whole image



Driving principle



Advantage of the MEMS inertia drive actuator

- Act on the other objects
- Long driving displacement
- Large generation force

Other MEMS device in JAXA

- Inertia sensor (accelerometer, gyroscope)
- MEMS oscillator
- Etc…

Conclusions

Make it smaller

With nano-scale fabrication precision

- Reduced mass and volume of the satellite
  - High cost performance (Launch cost: ~1,000,000 yen/kg)
  - Reachable region depend on the satellite weight
- Multiple functions are integrated
  - Higher performance

Problems

- Harsh environment
- High reliability is required
- Most devices on the market are not for space application.
  - Newly development is required
  - Some of them can be used in space by re-packaging with MEMS technology.

High development cost

Frontier of MEMS

- In space and astronautical area, MEMS device is required strongly.
- Especially space and astronautical science area require small and high-performance devices.

Space and astronautical science area is a frontier of MEMS devices and technologies.

Study of MEMS Devices for Space Applications

The 20th Microelectronics Workshop
October, 2007

Tetsuhito Arakawa

Electronic, Mechanical Components and Materials Engineering Group, Institute of Space Technology and Aeronautics of JAXA

What is MEMS?

MEMS: Micro Electro Mechanical Systems

are the integrated devices with various types of functions in the fields of mechanics, electronics, optics, and chemistry through semiconductor microfabrication techniques.

S.Shoma，MEMS開発＆活用スタートアップ，p9.

Examples of commercial off-the-shelf products application

- Airbag
- Game player ･･････････ Acceleration sensor
- Projector ･････････････ Digital micromirror device
- Printer ･････････････････Ink-jet printer head
- Medical devices ････････Micropump

Features of MEMS device

◆Downsizing and weight saving device

For microfabrication applied by semiconductor process.
For integration of structure and electronic circuit.

◆Implementation of various functions

For utilizing various physical phenomena such as mechanics, electronics, optics, and fluid.

◆Low cost

Similar to semiconductor process, MEMS can be mass-produced with good and stable quality.

Background－Why MEMS for spacecraft?－

・Short development time
・Diversification of risks
・Low cost

Smaller spacecrafts are desirable.
But the functions and the performance should be the same or better.

Small and power-saving parts that equip special functions and performance necessary for space mission are required

Table 1. Satellite Classification
（Cited reference-University of Surrey SSHP: http://centaur.sstl.co.uk/SSHP/ ）

Group Name		Wet Mass
Large satellite		1[t] as a minimum
Medium sized satellite		500～1000[kg]
Small satellite	Mini satellite	50～500[kg]
	Micro satellite	10～50[kg]
	Nano satellite	1～10[kg]
	Pico satellite	0.1～1[kg]
	Femto satellite	0.1[kg] as a maximum

Achievements in space/high-altitude area（U.S）

Type	Spacecraft	purpose	Launch	Note
Acceleration sensor	MARS Polar Lander	Practical use	1999	
RF switch	PICOSAT	Experi-mental	2000	
Gyroscopic acceleration sensor	MEPSI	Experi-mental	2002	
RF switch	ARCADE (balloon)	Practical use	2006	35 km high
Vibration gyroscopic sensor	TacSat-2	Practical use	2006	Inertial compass combined with a star camera

DARPA：the Defense Advanced Research Projects Agency

Achievements in space/high-altitude area（JPN）

Type	Spacecraft	purpose	Launch
Vibration gyroscopic	SOHLA-1	Practical use	Scheduled in 2008
Acceleration sensor	HⅡ-A	Practical use	—

Challenges for space application

◆Function and performance

Specific requirements for spacecrafts should be satisfied.

◆Reliability

Improvement of standards and test methods
Clarification of failure mechanism differing by the constructions and the principle of operation.

Temperature, vibration, shock, radiation, static build-up, and sticking

◆Cost

High-mix and low-volume---No standards for production process.

Research in Electronic, Mechanical Components and Materials Engineering Group

The research on MEMS has been conducted in various groups of JAXA as necessary. Our Electronic, Mechanical, Components, and Materials Engineering group has started conducting full-scale research in 2006 on MEMS for space application in anticipation of future downsizing and multi-functional spacecrafts.

Research in Electronic, Mechanical Components and Materials Engineering Group

1. Investigation on MEMS parts

   Continued investigation on technological trend in/outside of Japan

2. Research on development of MEMS parts

   Goal: Development of the parts equipped with functions, performance, and reliability for space application
   -Acquire the design and the process technology and develop components for space use.
   Implementation: Design and produce a prototype with the cooperation of external institutions such as an university.

3. Evaluation of COTS for space application

   Goal: Establishment of application and evaluation method for COTS

   The following parts are under evaluation
   －Acceleration sensor
   －RF switch

COTS Evaluation for Acceleration Sensor

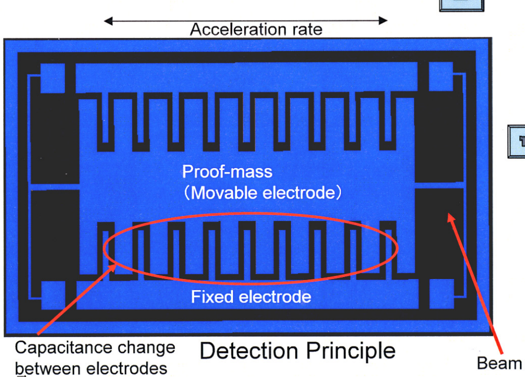
Detecting System:
Capacitance change

Measuring Range:±1.7G

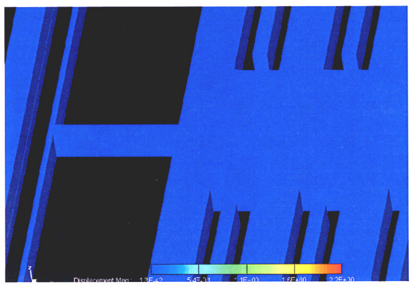
Resolution:1mG

Sensitivity Axis:2 axes

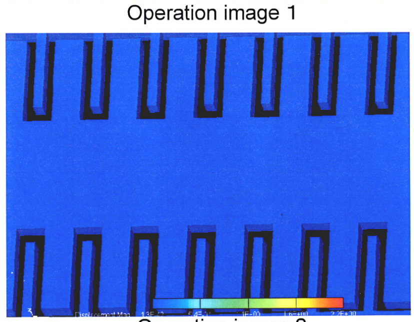
Operation Temperature:－55～＋125℃



Detection Principle



Operation image 1



Operation image 2

COTS Evaluation for Acceleration Sensor

Test Item	Condition	Result [No. of defects]
Vibration	20-2000Hz sweep 20G	0／5
Random vibration	MIL-STD-202 Condition H（34.02Grms）	0／5
Shock	3000G、>0.3ms	0／5
Temperature cycling	150℃(30 min.)／-55℃(30 min.) 1250 cycles	0／5
High-temperature operation	125℃、2000-hour Test pin applied ON/OFF repeated	0／5
ESD	HBD 3000V	Planning
Radiation TID／SEE	Under review	Planning

These are set up based on MIL-STD-883.

COTS Evaluation for RF Switch

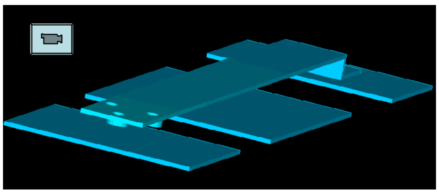
Drive System：Electrostatic force

Frequency Range：DC～7GHz

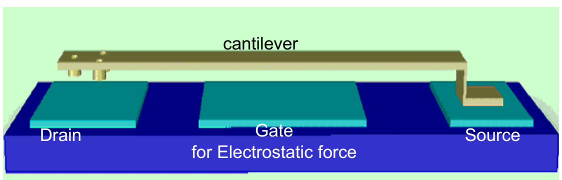
Insertion Loss：＜0．1dB ＠＜1GHz

Switching Speed：＜100μs

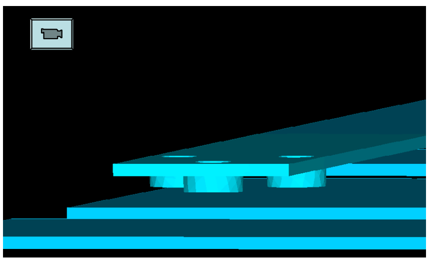
Operation Temperature：0～＋70℃



Operation image 1



Operation Principle



Operation image 2

COTS　Evaluation for RF Switch

Test Item	Condition	Result [No. of defects]
Vibration	20-2000Hz sweep, 20G	0／5
Random vibration	MIL-STD-202 Condition H (34.02Grms) Switch instantaneous interruption (1V、1mA)	0／5
Shock	3000G、>0.3ms Switch instantaneous interruption (1V、1mA)	0／5
Temperature cycling	150℃(30min.)／-55℃(30min.) 1250-cycle	0／5
High-temperature operation	ON fixed　2000-hour ON/OFF repeated 2000-hour	Planning
ESD	HBD 3000V	Planning
Radiation TID／SEE	Under review	Planning

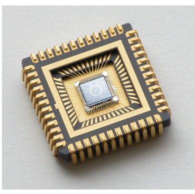
These are set up based on MIL-STD-883.

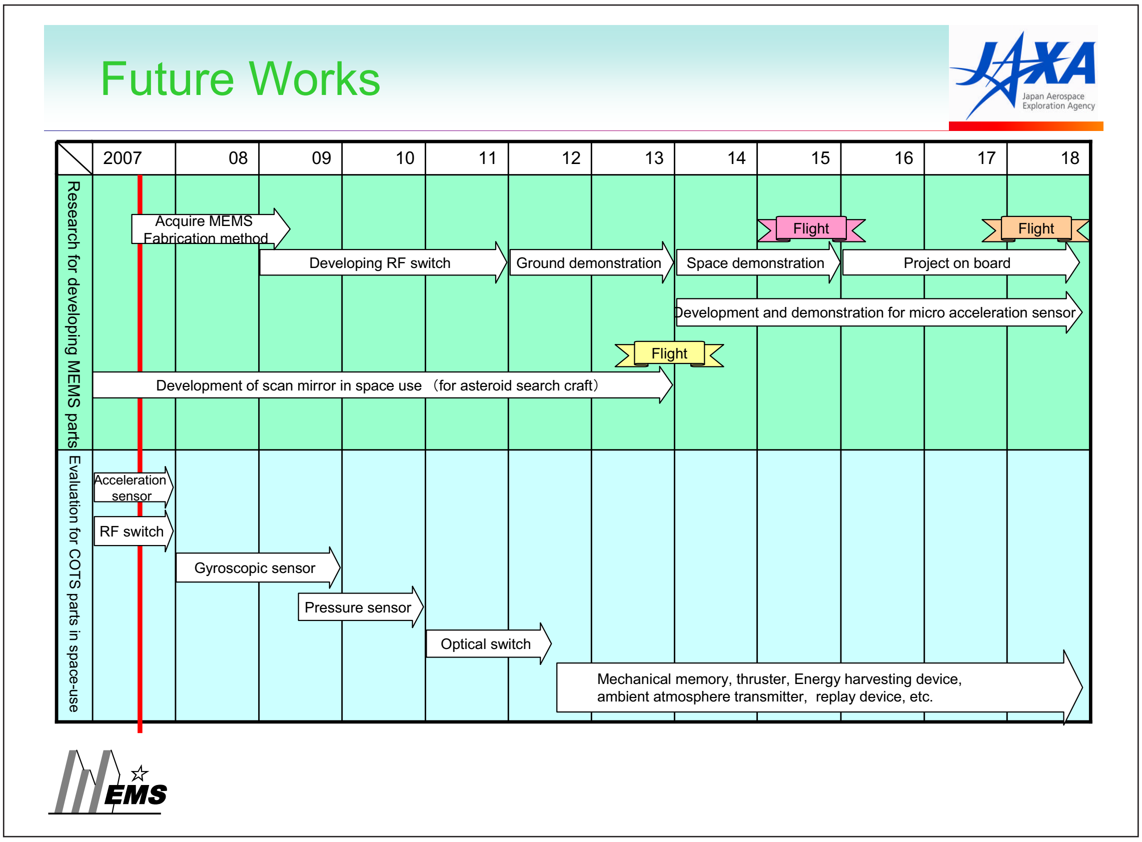
Future Works

1. Research for developing MEMS parts
   Targeted type : RF switch, Micro-acceleration sensor, Scan mirror, etc.

   ･Construction of design platform
   ･Construction of manufacturing process
   ･Trial production of major component

2. Evaluation for COTS in space use
   ･Expansion of targeted types
   (gyroscopic, pressure sensor, RF filter, and etc.)
   ･Review of evaluation system for reliability




Future Works
JAXA
Japan Aerospace Exploration Agency
2007
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18
Research for developing MEMS parts
Acquire MEMS Fabrication method
Flight
Flight
Developing RF switch
Ground demonstration
Space demonstration
Project on board
Development and demonstration for micro acceleration sensor
Flight
Development of scan mirror in space use （for asteroid search craft）
Evaluation for COTS parts in space-use
Acceleration sensor
RF switch
Gyroscopic sensor
Pressure sensor
Optical switch
Mechanical memory, thruster, Energy harvesting device,
ambient atmosphere transmitter, replay device, etc.
MEMS

MITSUBISHI 三菱電機 Changes for the Better

第20回マイクロエレクトロニクスワークショップ講演
THE 20th Microelectronics Workshop

衛星搭載部品の課題と将来展望
Issues of Parts on Satellites and Future Prospects

2007-10-30

三菱電機株式会社
MITSUBISHI ELECTRIC CORPORATION
KAMAKURA WORKS

Space Systems Department Parts Engineering Section Manager
Naonobu Fujimoto

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目次 PRESENTATION CONTENT

1. Introduction of MELCO
2. Current states of parts for satellite
3. Issues of Parts on Satellites
4．Adoption promotion of parts made in Japan
5. Ideas of parts for satellite
6. JAXA－MELCO component development

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三菱電機の紹介 WHAT IS MELCO

Changes for the Better

三菱電機は確かな技術力で、ソリューションビジネスの未来を支えています。

The future of Our“Solutiopn Producing Business”Will be realized by incorporating our Provent technical Capa bilities.

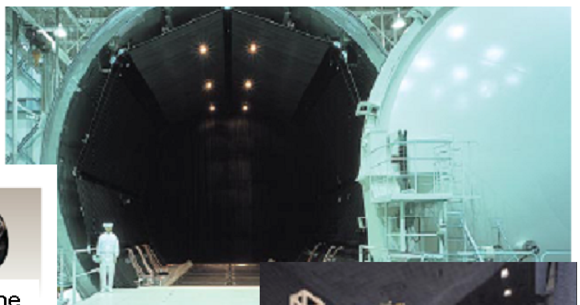
MITSUBISHI 三菱電機

三菱電機の紹介 WHAT IS MELCO KAMAKURA

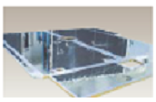
Changes for the Better

日本で唯一衛星の設計ー製造ー試験が一貫して出きる工場

The Kamakura Works is a factory that can only do the one continuous operation of the satellite (design, manufacturing, and examination) in Japan.



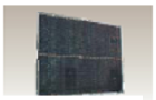
Space Chamber



Heat Pipe Panel

Beacon Transmitter

Ion Engine



SolarArray Panel

SSPA

Lithium ion battery

Compact Antenna Test Range

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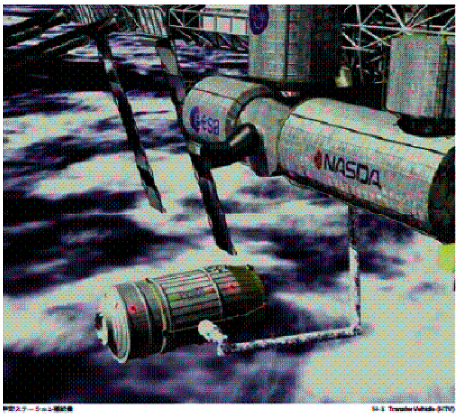
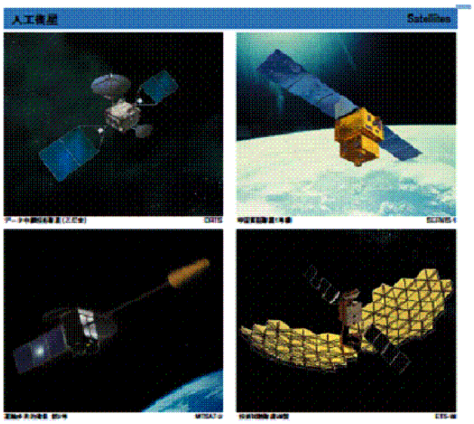
MITSUBISHI 三菱電機 **三菱電機の紹介 WHAT IS MELCO KAMAKURA** *Changes for the Better*

The Kamakura Works has produced various kinds of devices for more than 200 satellites. Based on these track records, we are producing new products to reduce the weight, extend the life span and to improve the performance of various satellite systems.





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MITSUBISHI 三菱電機 **衛星搭載用部品の現状Current states of parts for satellite** *Changes for the Better*

表1は、衛星搭載部品点数等の分析結果である。

Table 1 is the analysis results of the number of parts equipped with the satellite.

・部品点数は約30万点

●The number of parts is about 300,000 points.

・全体の部品点数の70%以上が輸入部品である。

●70% or more of the entire number of parts is the import parts.

・EEE部品は衛星全体の金額ベースで約10%位である。

●EEE parts are about 10% of the amount of money of the entire satellite.

▪輸入部品は品種数で80%／金額ベースで70%をしめる。

●The import parts are the entire about 80% in the number of kinds. 70% in terms of monetary amounts.

▪IC／Tr／Diで金額ベースで40%をしめる。

●IC/Tr/Di in the amount of money base　About 40% or more

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Table1 the analysis results of the number of parts

	Parts	KINDS TOTAL	JAXA	MIL	ESA(ESCC)	SCD JAPAN	SCD Import	Domestic rate KINDS	Domestic rate Money	money ratio each parts
1	IC	58	3	40	7	1	7	7%	7%	25%
2	Tr	20		11	1	2	6	10%	2%	12%
3	Di	36		23			13	0%	0%	6%
4	C	31	14	6	2	3	6	55%	58%	4%
4.1	Chip	10	6	1		1	2	70%	89%	1%
4.2	Lead	21	8	5	2	2	4	48%	42%	3%
5	R	16	5	10		1		38%	36%	2%
5.1	Chip	3		2		1		33%	36%	2%
5.2	Lead	13	5	8				38%	37%	0%
6	CONNECTOR	71	5	25	18	1	22	8%	4%	5%
7	Crystal Osc	5				1	4	20%	8%	1%
8	Relay	3		1			2	0%	0%	1%
9	Torance/coil	35		10		24	1	69%	72%	1%
10	Wire	32	3	6		2	21	16%	1%	6%
11	PWB	3	3					100%	100%	1%
12	Thermistor	4	1	2			1	25%	86%	3%
13	Fuse	2					2	0%	0%	4%
14	Other	46		1	1	3	41	7%	60%	26%
15	mecha compo	3				2	1	67%	93%	1%
	Total	365	34	135	29	40	127			100%
	Ratio	100.00%	9.32%	36.99%	7.95%	10.96%	34.79%	20%	35%	

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Issues of Parts on Satellites

Changes for the Better

搭載用部品は品質問題が途切れない。以下に原因の分析結果を記載する。

As for parts for the satellite, the quality issue doesn't become interrupted. The analysis result of the cause is described as follows.

■宇宙用MIL部品の生産縮小の影響

Influence of production reduction of MIL parts for space.

→ 98年から02年頃M&Aや工場閉鎖が頻繁に起こっており、ラインの不安定からの不良が出ている。

M&A and the factory closedown have happened frequently in around 02 since 98 years, and inferior parts from the instability of the line are made.

↓

最近は、在庫品の枯渇から新規製作品にロット不良が頻発。

Recently, the stock disappears and a defective lot happens frequently to a new manufacture.

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■出荷検査（スクリーニング）で不良品を除く発想になっている。
（不良品はある確率で存在する）

It is a conception to exclude defective parts by screening.
(Defective goods exist at a certain probability.)

→システムメーカとしては**輸入部品には性悪説**で対処。

The system maker deals with the import parts by the inherntly evil.

■**PINDやRGA等の不安定なスクリーニング方法**にたよっている。

It relies on unstable screening methods such as PIND and RGA.

→各社の検出感度が違う等の問題が提起されている。

The problem with different detection sensitivity of each company is instituted.

■衛星搭載用部品は古い構造であり、製造設備のメンテナンスが難しくなっている

Parts for the satellite are old structures, and the maintenance of manufacturing facilities is difficult.

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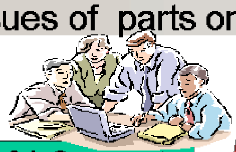
Issues of parts on satellites(Length delivery)

USA



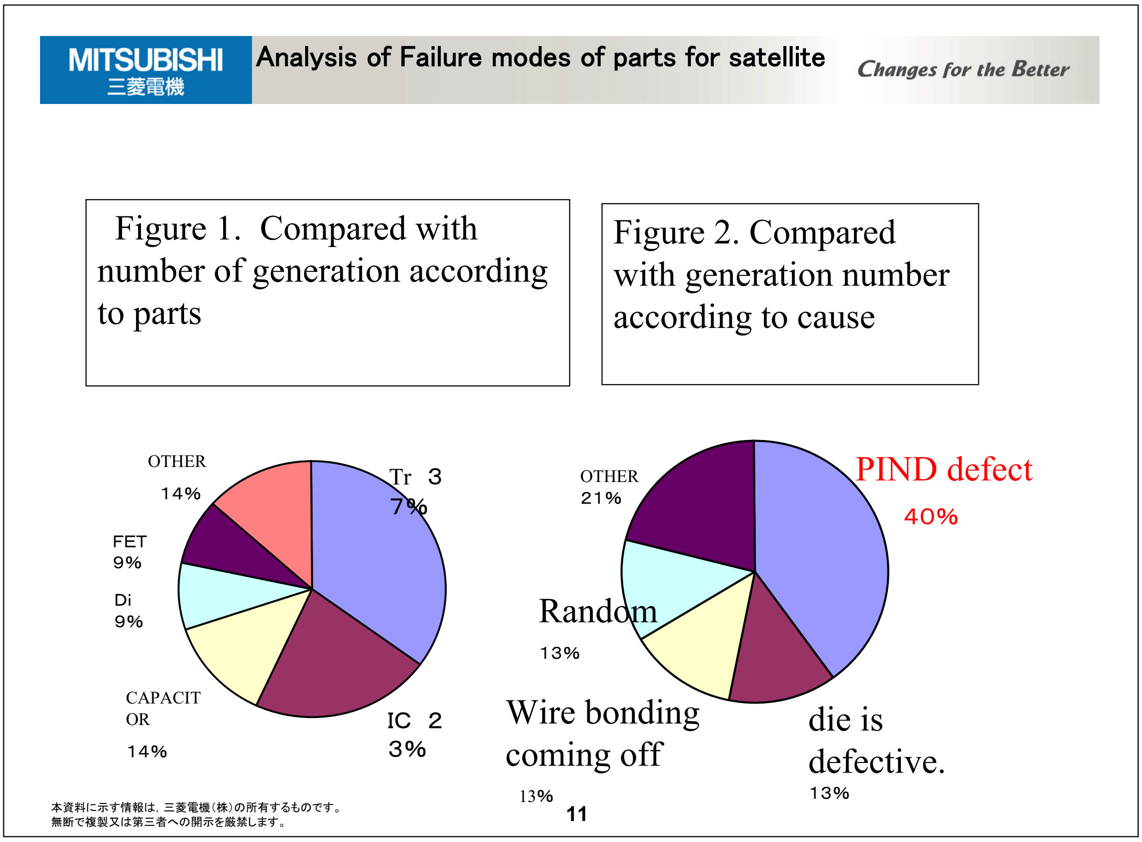
·Rapid expansion of U.S.A. Government procurement
·Stock disappears of parts inventory
·Single manufacturing maker's resource shortage
·Superannuation of old process line
·Rapid start-up of production line
·Age/shortage of processing technology person
·Age/shortage of quality control engineer
·Limit of selection by screening

Shortage stock /Poor quality

JAPAN

·Delivery date delay
·The manufacturing lot is defective.
·The access to information is difficult in ITAR.

CASE
- Delivery date delay/alert problem of MSC Co. 1N5811etc Di
- TELEDYNE Co. CAN RELAY sealing LOT is defective.
- SSDI Co. Substrate crack of metal packing diode
-IR Co. FET PIND defective /sealing defective.
-KEMET Co. ceramic capacitor element crack
-AVX Co. ceramic capacitor Boyd defective insulation
- SEMICOA Co. Tr 2N3501 PIND defective
- Alert VISHAY Co. winding resistance delivery date delay/problem
- Honeywell1MSRAM alert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Analysis of Failure modes of parts for satellite
Changes for the Better
Figure 1. Compared with number of generation according to parts
Figure 2. Compared with generation number according to cause
OTHER
14%
Tr 3
7%
FET
9%
Di
9%
CAPACITOR
14%
IC 2
3%
OTHER
21%
PIND defect
40%
Random
13%
Wire bonding coming off
13%
die is defective.
13%
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Failure cases with parts for satellite
Changes for the Better
FET Characteristic Difference
FETの特性バラツキ
Defective difference in process of Capacitor
コンデンサの工程内不良バラツキ
チップ抵抗膜剥がれ
ワイヤボンド部異常
ガラスハーメ部の金属コンタミ不良
セラミックコンデンサデラミネーション
シール部不良
Sn
Fe

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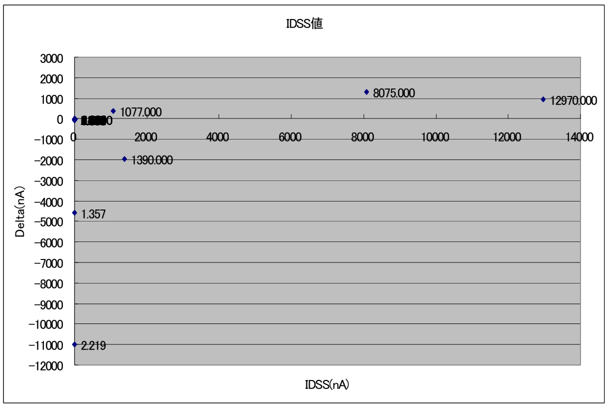
Failure cases with parts for satellite

Changes for the Better

CAPACITOR Lot History FET Characteristic difference

LDC	Quantity	Reject	rate
9939A	2083	0	0%
9950C	2700	0	0%
0129A	3046	5	0.16%
0129D	3894	9	0.23%
0208A	289	0	0%
0209B	504	0	0%
0210A	3106	6	0.19%
0335D	848	0	0%
0446Z	1736	0	0%
0410D	306	0	0%
0426B	1742	0	0%
0521A	700	3	0.42%
0522B	778	6	0.77%
0523B	676	6	0.88%
0544E	2483	3	0.12%
0612A	453	1	0.22%
Total	25344	39	0.15%



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Future Prospects

Changes for the Better

1. To select Parts from Japanese Development Components (e.g. Earth Sensor)

   (1) High Quality/Reliability

   (2) Reasonable Parts' Cost

   (3) Reduce Recurring Cost

   Reason why (a) Easy Procurement from Japanese High Quality Parts (b) Reduce Total Cost concerned with EL Management Cost and Parts Failure Analysis Management Cost

⇒Final Purposes are To Select Japanese Parts as much as possible and To Contribute To Last for Japanese Economic Activation

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MITSUBISHI 三菱電機

Future Prospects

Changes for the Better

2. To Cooperate with JAXA for Strategic Development Parts accordance with Japanese Government Policy and To join Japanese Parts' Investigation Committee about Reasonable Parts' Procurements Cost

MPU/ASIC/FPGA/Memory/Crystal Oscillator

Selecting Guideline of Strategic Parts

(1) Parts of achieved Original System Design for Necessary

(2) Parts composed of Important Basic Technology with Components' Quality Assurance

(3) Parts for Only Space Application with restriction from ITAR and/or EL

(4) Parts Secured of Competition in the international market

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Future Prospects

Changes for the Better

3. To Investigate Space Application related General-purpose Device(Tr, Di etc.)

(1) To Select European Parts

(2) To Evaluate PEM Parts from Automotive Application PEM

But, To Propose Support Budget From Japanese Government because of Spending Big Cost for These Evaluations (Radiation, Life, Reliability etc.)

In Now, Space Applications of Tr, Di employ Rare Constructions(Metal Can Case and Glass Sealing) and We Have Many Trouble about These Sealing Construction

⇒ To Apply Space Hardwere for Improvement on Quality/Reliability related Japanese PEM Parts including Surface Mount Technology

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Future Prospects

Changes for the Better

4. Passive Parts (Resistors/Capacitors/Coils etc.) and Printed Wiring Board are Procured from Japanese Manufactures Because of Design Easiness and Flexibility

5. In Now, To investigate JAPAN PARTS CENTER Concept at SJAC(The Society of Aerospace Companies) Committee (see Next Page)

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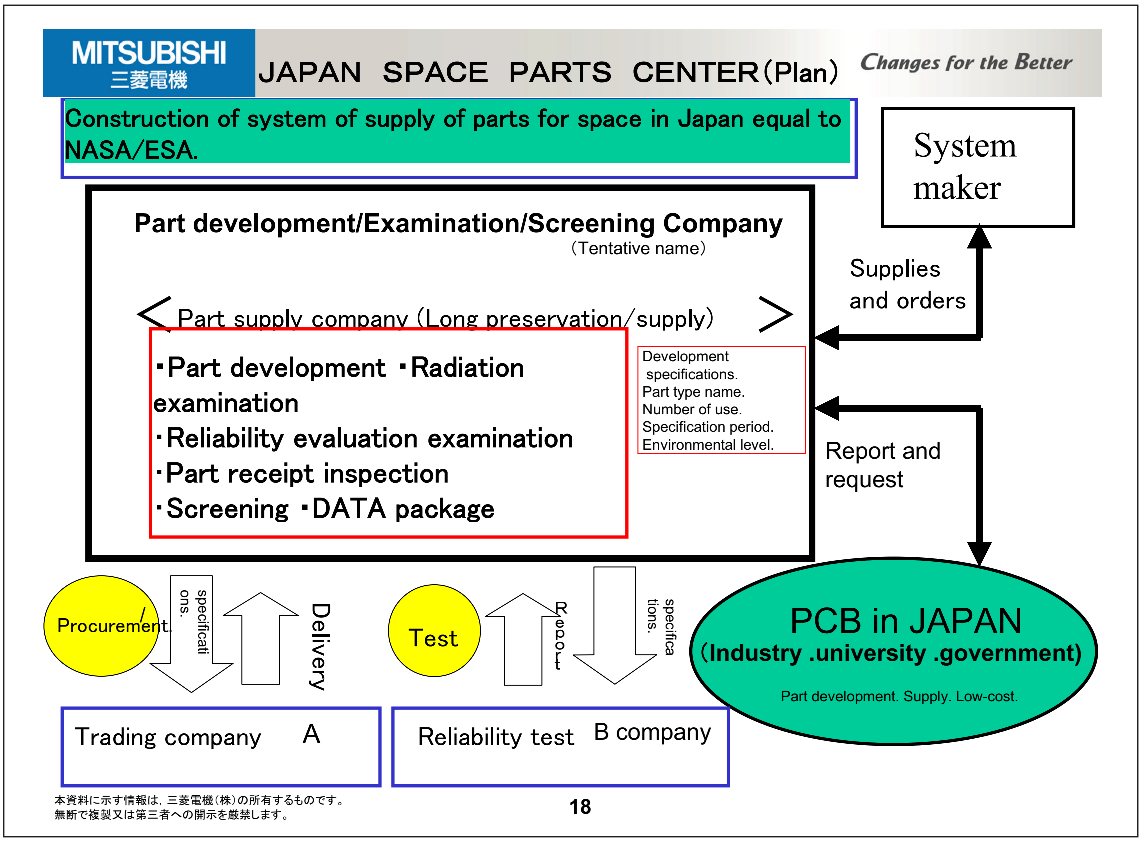


MITSUBISHI 三菱電機 Adoption promotion of parts made in Japan *Changes for the Better*

Difference of idea to quality

made in Japan	import part
製造プロセス重視 Manufacturing process respect 工程内不良は常にフィードバック The defect in the process always Feedback.	スクリーニング重視 Screening process respect
スクリーニング/出荷検査はゼロ不良 Screening/shipment inspection is 0 defects	スクリーニング／出荷検査で不良品検出 Screening/shipment inspection defective parts detection.
出荷後の不良品昆入PPMオーダ Defective Parts after ships are PPM orders.	出荷後の不良品混入は確率的にあり Defective goods after ships it are probabilistic.

本資料に示す情報は，三菱電機(株)の所有するものです。
無断で複製又は第三者への開示を厳禁します。

MITSUBISHI 三菱電機 衛星搭載用部品の考え方 Ideas of parts for satellite *Changes for the Better*

創造

●Creation

技術的ブレークスルー

●Technical breakthrough

過去の常識との融合

●Uniting with past common sense

新常識の決定

●Decision of new common sense

本資料に示す情報は，三菱電機(株)の所有するものです。
無断で複製又は第三者への開示を厳禁します。

MITSUBISHI 三菱電機 衛星搭載用部品の考え方 Ideas of parts for satellite *Changes for the Better*

和と洋の融合

Grow together of JAPAN andEurope / America

私たちは、MADE IN JAPANの高品質・高信頼性もの作りと欧米の創造性豊かな発想のGrow togetherによる衛星搭載用部品の革新を望む。

We hope for the reformation of parts for the satellite.

It is achieved by Grow together of MADE IN JAPAN (one making with the high quality and high reliability) and Europe and America (creative conception).

本資料に示す情報は、三菱電機(株)の所有するものです。
無断で複製又は第三者への開示を厳禁します。

MITSUBISHI 三菱電機 JAXA—MELCO component development *Changes for the Better*

開発コンポ例 Example of development component

- **●小型送受信機の開発 Miniaturization SSPA**
- **●小型軽量化電源の開発） Miniaturization power supply**
- **●低衝撃保持解放機構の研究開発 Miniaturization LSRD**

要求 REQUEST

1）世界最高水準の高機能化 Making of the world highest level high erformance

2)世界最高水準の軽量・小型化 Lightness and miniaturization of the world highest level

3)低コスト化 Lowering the cost

●自動車用途部品の宇宙用への評価採用(軽量化でPEM部品採用)

Evaluation adoption for space of car usage parts(PEM parts)

●民需の実装技術の採用

Adoption of mounting technology of consumer products.

本資料に示す情報は、三菱電機(株)の所有するものです。
無断で複製又は第三者への開示を厳禁します。

JAXA CRK

High Reliability, Space use
Fixed Film Chip Resistors
JAXA CRK 16H、10H、8H、4H、2H

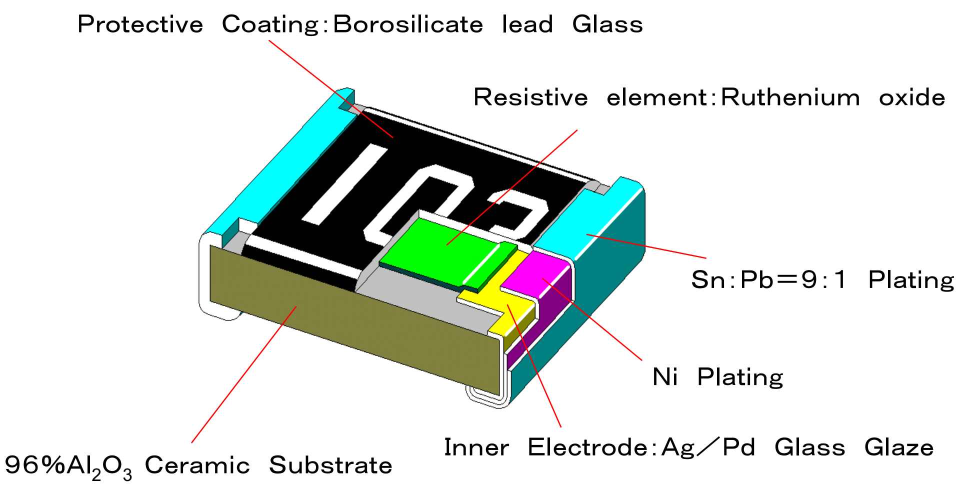
30th, Oct, 2007

TATEYAMA KAGAKU INDUSTRY CO. , LTD
TFC COMPANY

TATEYAMA KAGAKU INC

JAXA CRK

High Reliability, Space use Fixed Film Chip Resistors



TATEYAMA KAGAKU INC

JAXA CRK

High Reliability, Space use Fixed Film Chip Resistors

Product characteristics（JAXA CRK□□H□□□□R)

- Intended use: Satellites, Space station, Payload equipments, etc.
- Superior in stability, heat resistance, and vibration proof by glass coating
- Solder plating prevents Sn whisker generation
- Failure rate S level (0.001%/1000H) (assured)
- Total number of shipments since 1994 reaches 4Mpcs without trouble
- 100% screening , Lot assurance inspection, & periodic QCI

TATEYAMA KAGAKU INC

JAXA CRK

High Reliability, Space use Fixed Film Chip Resistors

Applicable specifications

JAXA－QTS－2000 **The common parts/materials, Space use, General specification for**

JAXA－QTS－2050 **Resistors, High Reliability, Space use, General specification for**

JAXA－QTS－2050／E201 **Detail specification**

Quality Assurance documents

S3SR－0701 **Quality assurance program plan**

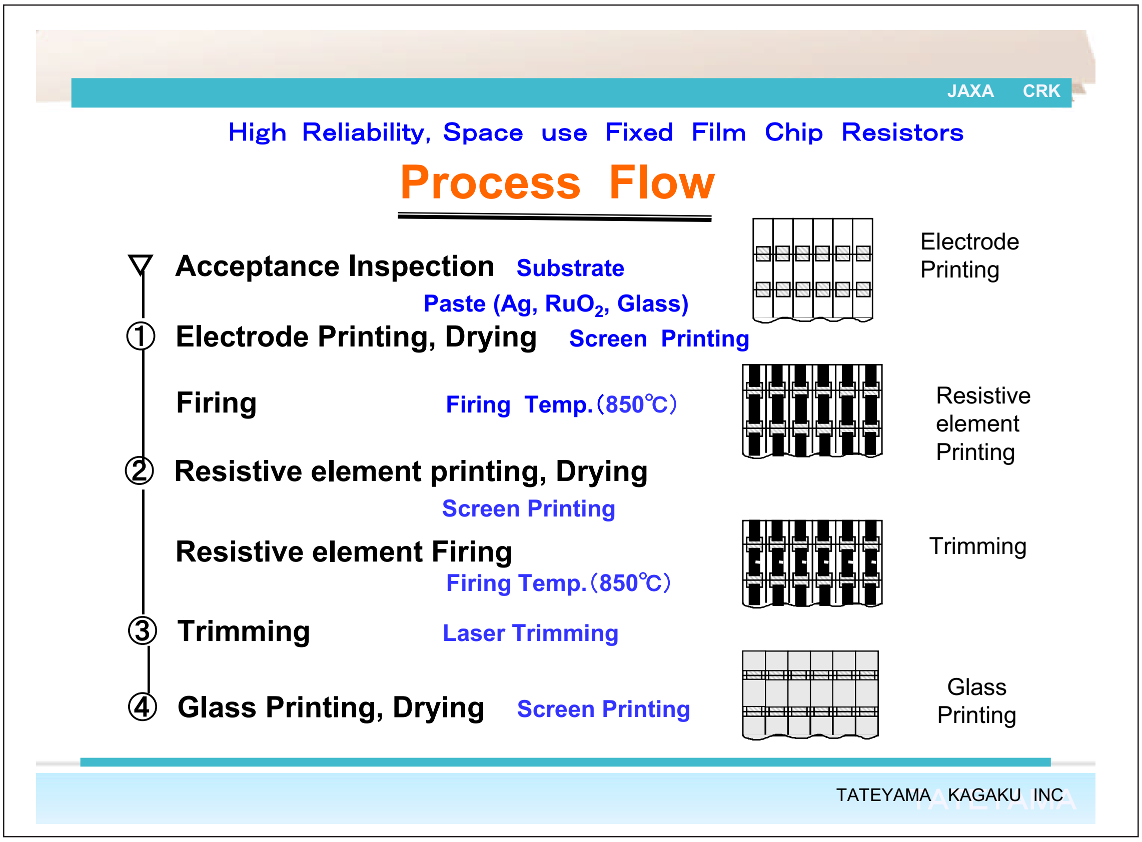
JAXA－ADS－2050／E201 **Application data sheet**

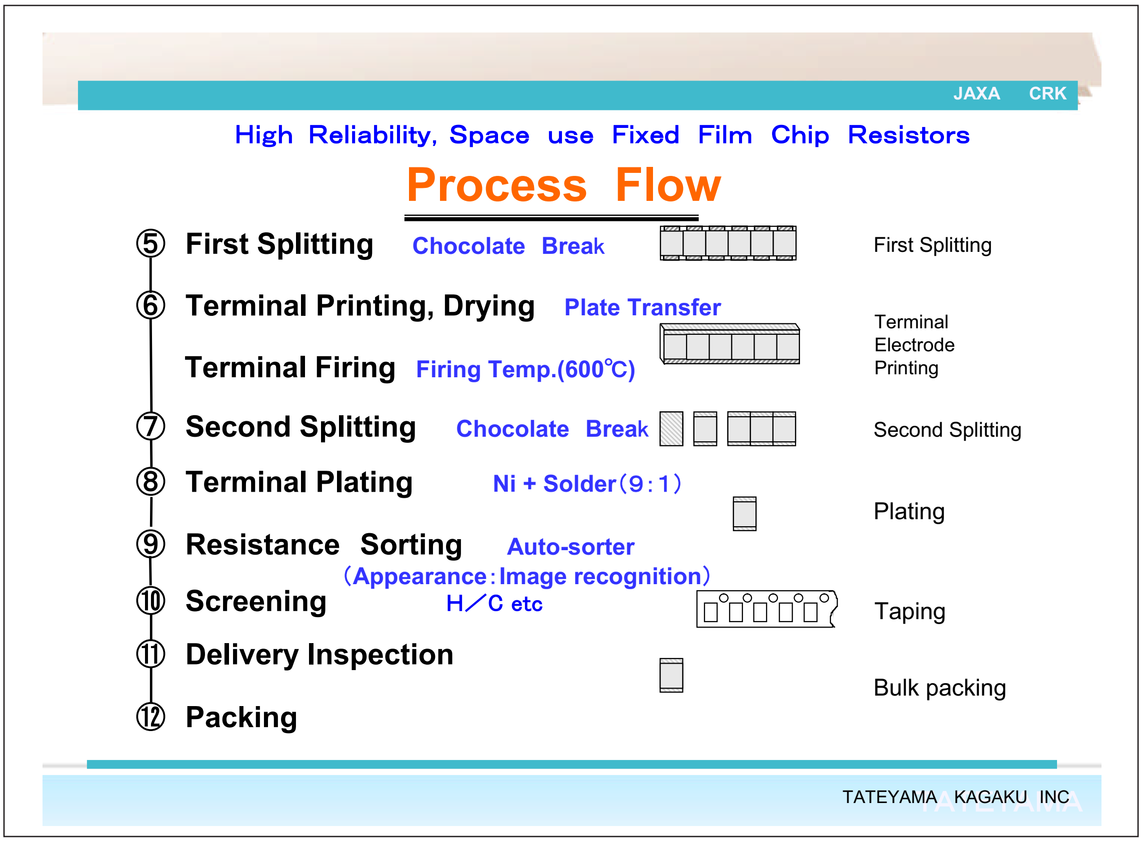
S3SR－0703 **TRB operational procedure**

Quality and environment management system

ISO－9001:2000 ISO－14001:2004 ISO／TS16949:2002

TATEYAMA KAGAKU INC

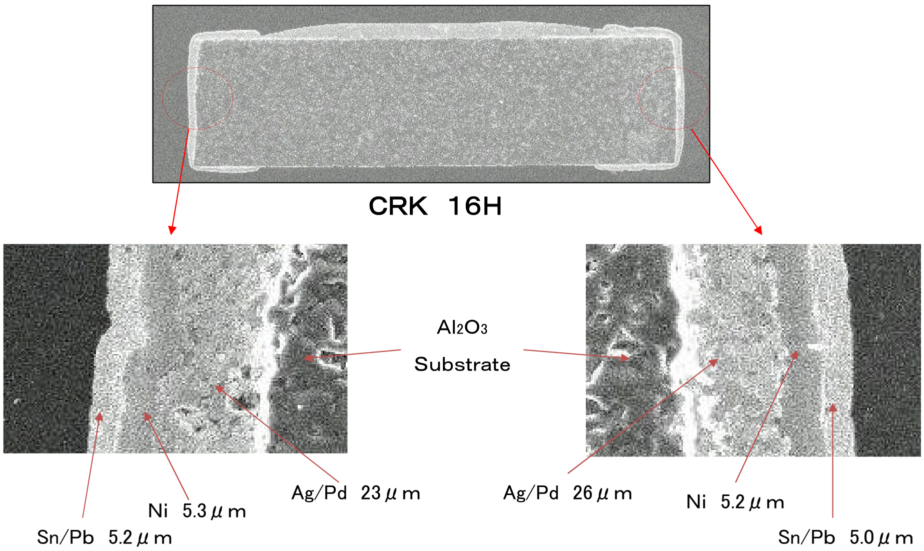

JAXA CRK
High Reliability, Space use Fixed Film Chip Resistors
Process Flow
Acceptance Inspection
Substrate
Paste (Ag, RuO2, Glass)
① Electrode Printing, Drying
Screen Printing
Firing
Firing Temp.(850℃)
② Resistive element printing, Drying
Screen Printing
Resistive element Firing
Firing Temp.(850℃)
③ Trimming
Laser Trimming
④ Glass Printing, Drying
Screen Printing
Electrode Printing
Resistive element Printing
Trimming
Glass Printing
TATEYAMA KAGAKU INC


JAXA CRK
High Reliability, Space use Fixed Film Chip Resistors
Process Flow
⑤ First Splitting
Chocolate Break
⑥ Terminal Printing, Drying
Plate Transfer
Terminal Firing
Firing Temp.(600℃)
⑦ Second Splitting
Chocolate Break
⑧ Terminal Plating
Ni + Solder(9:1)
⑨ Resistance Sorting
Auto-sorter
(Appearance:Image recognition)
⑩ Screening
H/C etc
⑪ Delivery Inspection
⑫ Packing
First Splitting
Terminal Electrode Printing
Second Splitting
Plating
Taping
Bulk packing
TATEYAMA KAGAKU INC

JAXA CRK

High Reliability, Space use Fixed Film Chip Resistors

DPA Analysis



TATEYAMA KAGAKU INC

JAXA CRK

High Reliability, Space use Fixed Film Chip Resistors

Rating

	Method	CRK16H	CRK10H	CRK8H	CRK4H	CRK2H
Category Temperature Range(℃)	E. 3. 5. 2	−55～+125				
Rated Ambient Temperature(℃)	E. 3. 5. 3	70				
Nominal Resistance Range(Ω)	E. 3. 5. 1	50mΩ or less、2. 0～1MΩ				
Critical Resistance (Ω)	−−	39K	220K	300K	160K	75K
Max Working Voltage (V)	−−	50	150	200	200	200
Rated Power(W)	E. 3. 5. 3	0. 0625	0. 1	0. 125	0. 25	0. 5
Rated Current(A)	E. 3. 5. 6	1. 0	1. 5	2. 0		
Max Overload Current (A)	E. 3. 5. 6	2. 0	3. 0	4. 0		
Resistance-Temperature Characteristic	E. 3. 5. 3	±200ppm／℃:M(2. 0～9. 1Ω)、±100ppm／℃:K(10～1MΩ)				

TATEYAMA KAGAKU INC

JAXA CRK

High Reliability, Space use Fixed Film Chip Resistors

100% screening, Lot assurance Test

Group	S/G	No.	Inspection	JAXA-QTS-2050 Test Requirement	JAXA-QTS-2050 Test Method	Decision Sample Size	Decision Quantity of Allowable Defects
A1	1	1	Heat Shock	3. 1. 4	4. 4. 4	All	PDA 5%
		2	High Temperature Proof	3. 1. 2	4. 4. 2		
		3	Resistance	E. 3. 6. 2	E. 4. 3. 5. 2		
	2	1	Externals, Dimension	E. 3. 3	E. 4. 3. 3. 2	AQL 2. 5%	
		2	DPA	E. 3. 4. 1	E. 4. 3. 4. 1	4	0
A2	1	1	Solderability	E. 3. 7. 1	E. 4. 3. 6. 1	10	0
	2	1	Resistance to Soldering heat	3. 1. 1	4. 4. 1	10	
	3	1	Substrate Bending	E. 3. 7. 3	E. 4. 3. 6. 3	10	

TATEYAMA KAGAKU INC

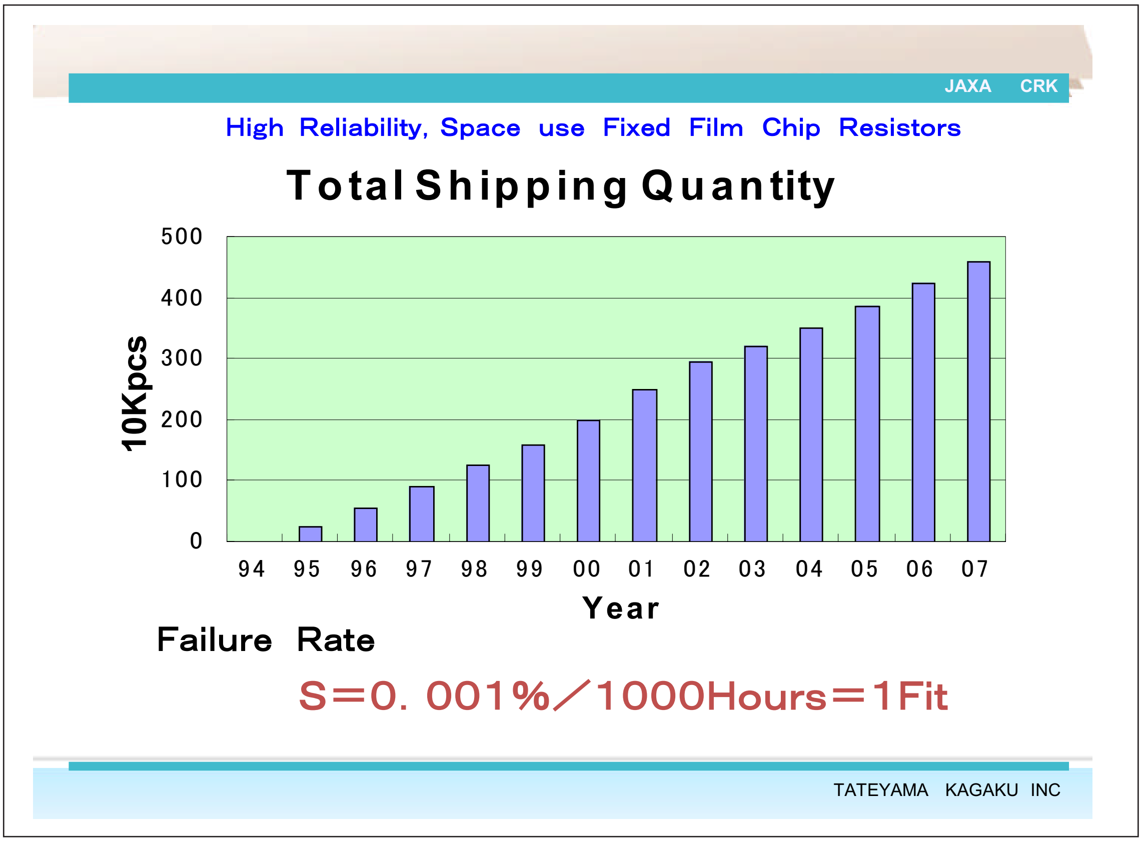
JAXA CRK

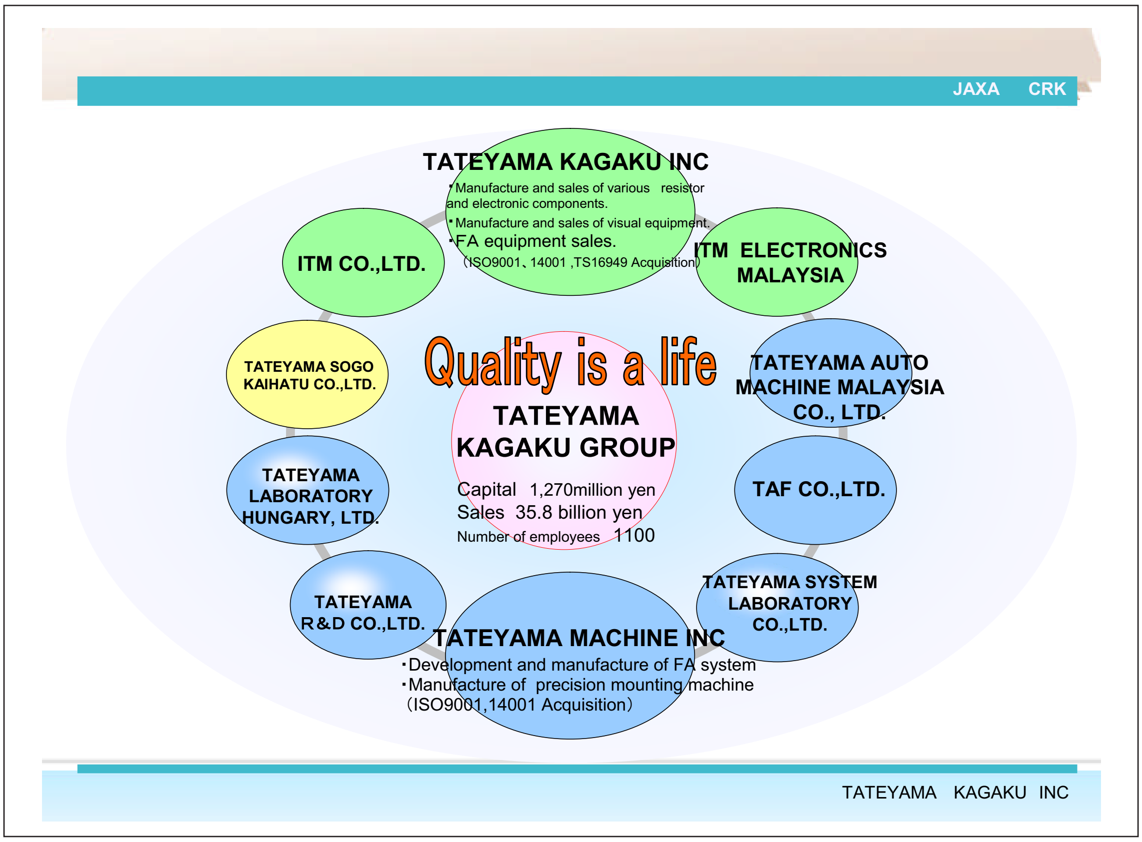
High Reliability, Space use Fixed Film Chip Resistors

Qualification Test

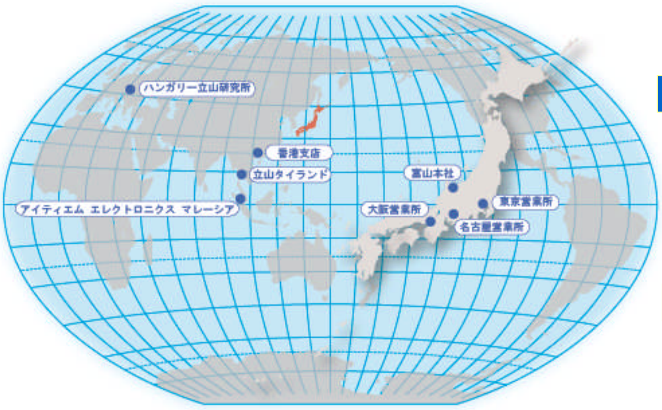
Group	S/G	Requirement	Inspection	Group	S/G	Requirement	Inspection
Ⅰ	1	E.3.6.1	Application of Pulse	Ⅵ	1	E.3.8.7	Stability
	2	E.3.6.2	Resistance	Ⅶ	1	E.3.7.4	Resistance to bonding exposure
ⅠA	1	E.3.3	Externals, Dimension		2	E.3.8.2	Shock
ⅠB	1	E.3.4.1	DPA		3	E.3.8.3	Thermal Shock(Ⅱ)
Ⅱ	1	E.3.6.4	Dielectric Withstanding Voltage	Ⅷ	1	E.3.8.1	Random Vibration
	2	E.3.6.5	Insulation Resistance	Ⅸ	1	E.3.7.1	Solderability
Ⅲ	1	E.3.6.3	Resistance-Temperature Characteristic		2	E.3.8.5	Resistance to Solvents
	2	E.3.8.6	Low Temperature Operation	Ⅹ	1	E.3.7.2	Adhesion
	3	E.3.6.6	Short-time Overload	ⅩⅠ	1	E.3.7.3	Substrate Bending
Ⅳ	1	–	Resistance to Soldering heat	ⅩⅡ	1	–	High Temperature Exposure
	2	E.3.8.4	Moisture Resistance	ⅩⅢ	1	–	Humidity (Steady State)
Ⅴ	1	E.3.9.1	Life	ⅩⅣ	1	–	Thermal shock

TATEYAMA KAGAKU INC


JAXA　CRK
High Reliability, Space use Fixed Film Chip Resistors
Total Shipping Quantity
10Kpcs
500
400
300
200
100
0
94 95 96 97 98 99 00 01 02 03 04 05 06 07
Year
Failure Rate
S=0. 001%／1000Hours=1Fit
TATEYAMA KAGAKU INC


JAXA　CRK
TATEYAMA KAGAKU INC
・Manufacture and sales of various resistor and electronic components.
・Manufacture and sales of visual equipment.
・FA equipment sales.
(ISO9001、14001 ,TS16949 Acquisition)
ITM CO.,LTD.
ITM ELECTRONICS MALAYSIA
TATEYAMA SOGO KAIHATU CO.,LTD.
Quality is a life
TATEYAMA KAGAKU GROUP
Capital 1,270million yen
Sales 35.8 billion yen
Number of employees 1100
TATEYAMA AUTO MACHINE MALAYSIA CO., LTD.
TATEYAMA LABORATORY HUNGARY, LTD.
TAF CO.,LTD.
TATEYAMA R&D CO.,LTD.
TATEYAMA SYSTEM LABORATORY CO.,LTD.
TATEYAMA MACHINE INC
・Development and manufacture of FA system
・Manufacture of precision mounting machine
（ISO9001,14001 Acquisition）
TATEYAMA KAGAKU INC

JAXA CRK



Group Headquarters・Plants

- Group Headquarters
- Oizumi Plant
- South Plant

Domestic Branch

- Tokyo Branch
- Osaka Branch
- Nagoya Branch

Overseas Branch

•TATEYAMA Auto Machine Malaysia	Shan Alam, Selagorehsan, Malaysia
•ITM Electronics Malaysia	Shan Alam, Selagorehsan, Malaysia
•TATEYAMA Raboratory Hungary	Budpest, Hungary
•TATEYAMA Thailand	Suanlung Thailand
•HONG KONG Branch	Kowloon Bay, Kowloon, Hong Kong

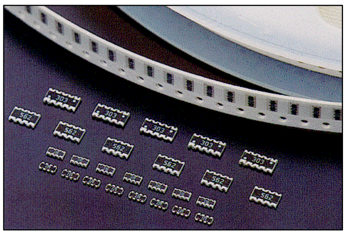
TATEYAMA KAGAKU INC

JAXA CRK

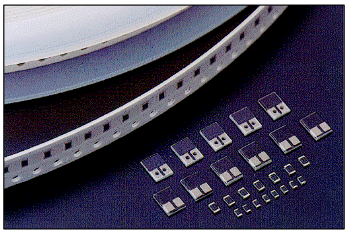
Company name	**TATETAMA KAGAKU IND.CO.,LTD**
Representative	**President Syoichirou Mizuguchi**
Capital	**99,500 thousand yen**
Date of Establishment	**May, 1958**
Number of Employees	**427**
Annual Turnover	**13.4 billion yen（Track record of 2006）**
Location Head Office	**30, shimonoban, Toyama**
Oizumi Plant	**1583, Chubu, 1-Ku, Oizumi, Toyama**
South Plant	**3-6, Tsukioka-Cho, Toyama**
Business Contents	**Manufacture and sales of Electronic Components and Equipment. FA Equipment sales.**

TATEYAMA KAGAKU INC

JAXA　CRK

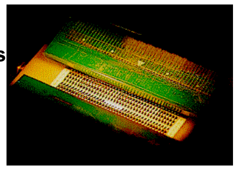


Network Resistor



Thermistor

Laser Trimming process
Reliability increases by precise and exact processing with the newest equipment.



TATEYAMA KAGAKU INC

JAXA　CRK

・Home Controller
・Push Button Transmitter

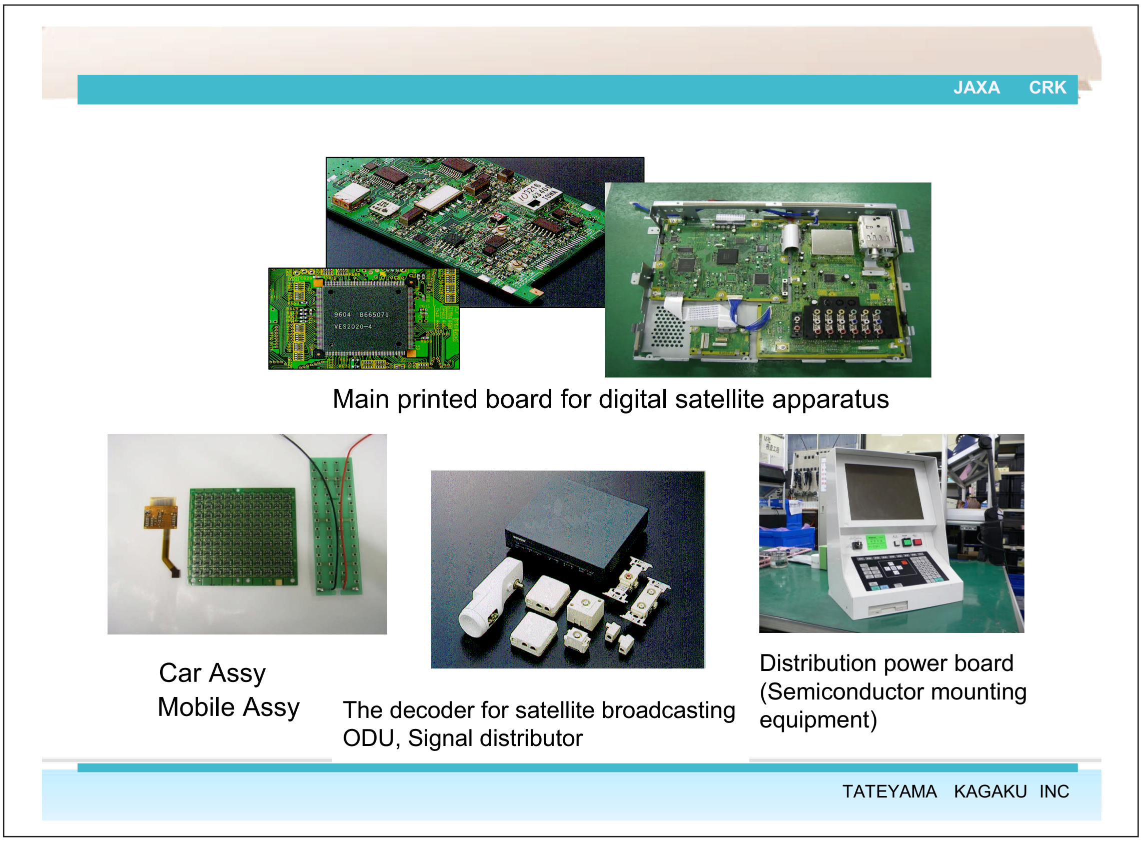
Pyro Sensor Transmitter

Passive Sensor Transmitter

Wireless Unit

RF Module

TATEYAMA KAGAKU INC


JAXA CRK
Main printed board for digital satellite apparatus
Car Assy
Mobile Assy
The decoder for satellite broadcasting
ODU, Signal distributor
Distribution power board
(Semiconductor mounting
equipment)
TATEYAMA KAGAKU INC

The 20th Microelectronics Workshop

Development status of SOI ASIC / FPGA

Oct. 30th 2007
Electronic, Mechanical Components and Materials Engineering Group, JAXA
H.Shindou

Background

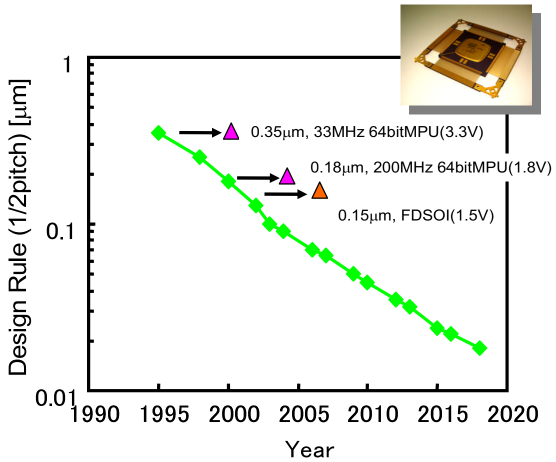
- In 2003, critical EEE parts for space use were selected at the Japan space EEE parts committee in order to develop advanced space systems.
- Programmable device (FPGA) was selected as one of the first phase items of critical components.

We started the feasibility study about FPGA based on 0.15μm FD-SOI technology.
We also started the development of SEU / SET hardened cell library for SOI ASIC.

SEU: Single Event Upset SET: Single Event Transient
FD-DOI: Fully depleted Silicon on Insulator FPGA: Field Programmable Gate Array
ASIC: Application Specific Integrated Circuit

Why we choose FD-SOI

- JAXA has developed LSIs with the latest technology for commercial market.
- For <0.18μm technology, SEEs are main concern for LSIs for space applications.
- FD-SOI is attractive for space because of its SEE hardness as compared with bulk technology.
(also suitable for Low power application.)



Design rule trend and JAXA's LSI roadmap

Now we plan to utilize the FD-SOI as a mainstream technology.

SEE: Single Event Effect

The 20th Microelectronics Workshop @ Tsukuba 2

PD-SOI vs FD-SOI

PD-SOI (Partially Depleted)

◆Thick SOI Thickness (T_{SOI}) ～0.1- 0.2um

◆Depletion Layer < T_{SOI}

↓

◇Large Floating body effect

◇High Drive Current by Kink effect

→ High speed application

◇Compatible Process with Bulk-Si

FD-SOI (Fully Depleted)

◆Thin SOI Thickness (T_{SOI}) < 0.05um

◆ Depletion Layer > T_{SOI}

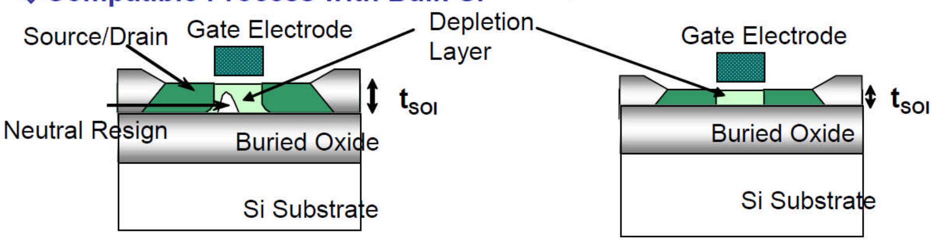
↓

◇Less Floating body effect

◇Better Subthreshold Slopes

→ Low-V_{th} is available

◇Process Issues in thin-film SOI



(Courtesy of OKI, quoted from 19MEWS material)

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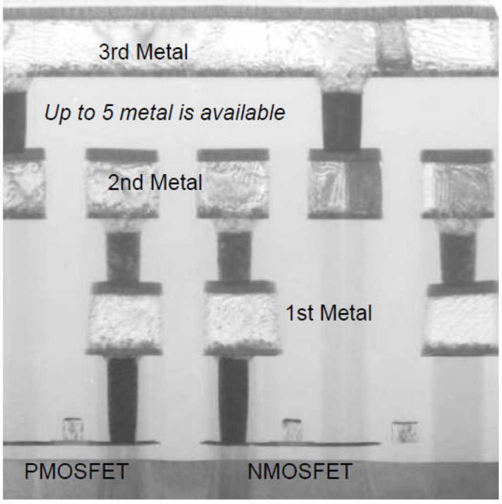
Oki FD-SOI Device Structure & Process

Cross-section TEM of 0.2um SOI



○Lpoly = 0.2 mm ○SOI Thickness under Gate = 50nm

Substrate : BONDED WAFER

◆0.35um SOI Process
- Gate length : 0.35um
- Gate Oxide thickness : 7nm
- Wiring Pitch : 1.4um

◆0.2um SOI Process
- Gate length : 0.2um
- Gate Oxide Thickness : 4.5nm
  4.5nm/7nm for 3.3V
- Wiring Pitch : 1.0um
- MIM, Inductor

◆0.15um SOI Process (shuttle)
- Gate length : 0.14um
- Gate Oxide Thickness : 2.5nm
- Wiring Pitch : 0.52um
- MIM, Inductor

⇨ - 0.15um SOI (Production line)
  LOCOS ⇒ STI
  Metal 0.52 ⇒ 0.39(1M)/0.48(<2M)
  BOX 200nm ⇒ 145nm
  Low Leakage (LL) Ioff<2E-12A/um

(Courtesy of OKI, quoted from 19MEWS material)

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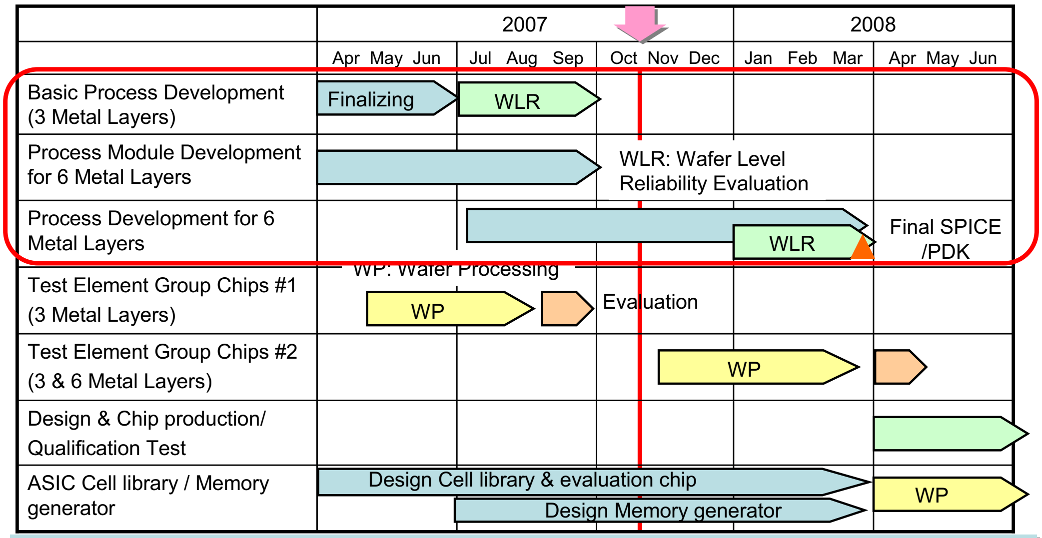
Development schedule (SOI process)



- Process development with 6 metal layers is in progress.
- Final SPICE/PDK is scheduled to be released at the end of fiscal year.

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Target Specification for ASIC / FPGA

- 0.15 μm commercial FD-SOI foundry with patented SEU/SET free primitive circuits. (RHBD techniques used)
- 1.5V for core and 3.3V for I/Os.
- SEU/SET free up to LET of 64MeV/(mg/cm^2)
- TID: 1kGy(Si) (100krad(Si))

ASIC & FPGA

Joint development with CNES / ATMEL

- SRAM based re-configurable FPGA. (Based on ATMEL architecture)
- 700k ASIC gates

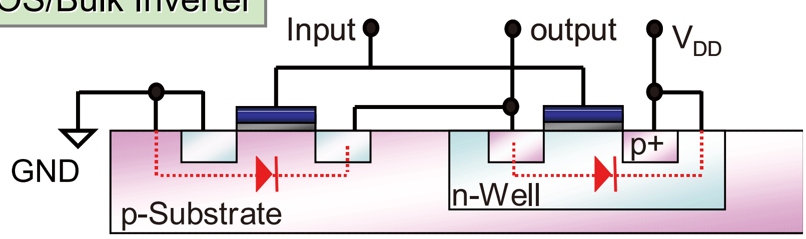
FPGA

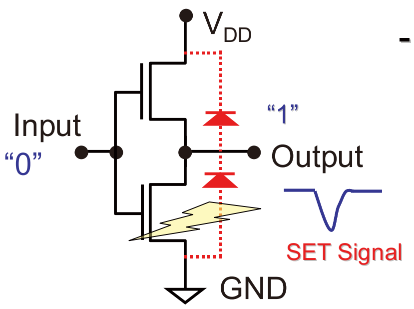
RHBD: Radiation Hardened By Design
TID: Total Ionizing Dose LET: Liner Energy Transfer

The 20th Microelectronics Workshop @ Tsukuba 6

Single Event Transient signal generation

CMOS/Bulk Inverter





- e-h pair generation by an Ion strike to the OFF-state transistor
- Reversed biased junctions collect charge
- Voltage transients propagate appreciable distances

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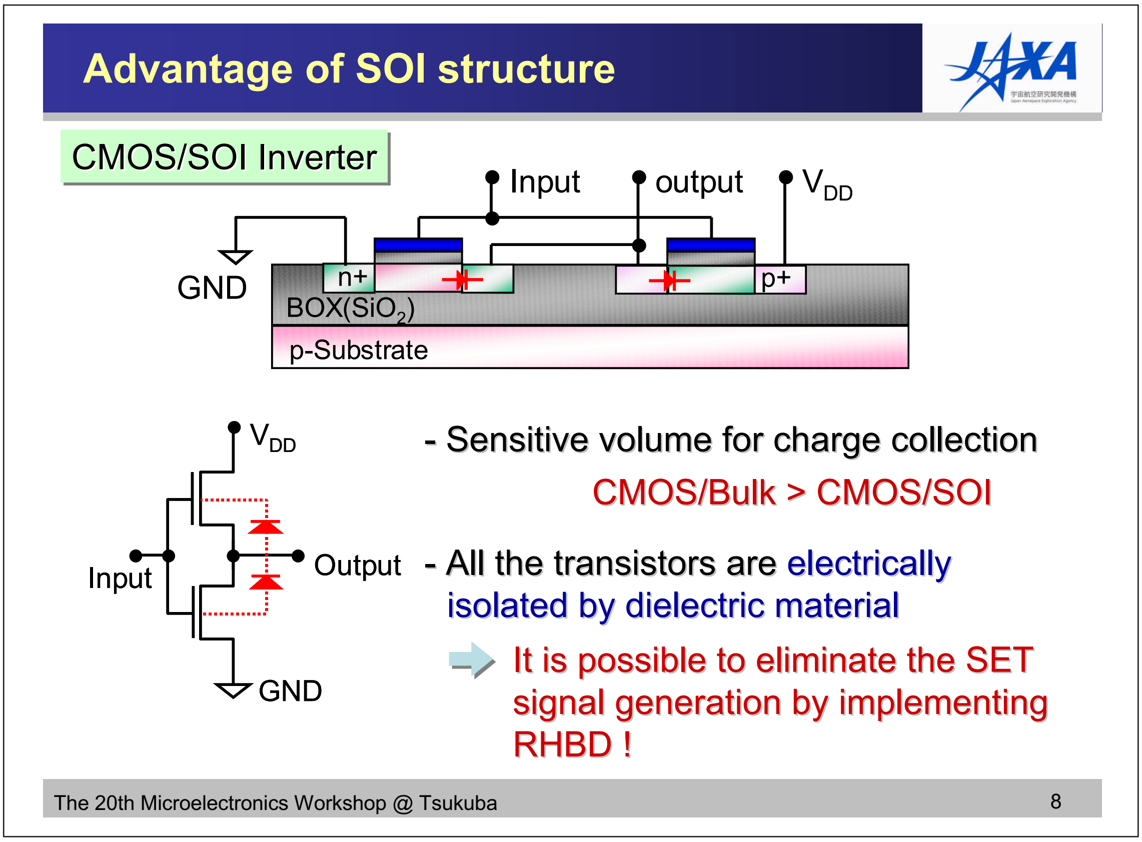
Advantage of SOI structure
JAXA
CMOS/SOI Inverter
Input
output
V_{DD}
GND
n+
p+
BOX(SiO_2)
p-Substrate
V_{DD}
Input
Output
GND
- Sensitive volume for charge collection
CMOS/Bulk > CMOS/SOI
- All the transistors are electrically isolated by dielectric material
It is possible to eliminate the SET signal generation by implementing RHBD !
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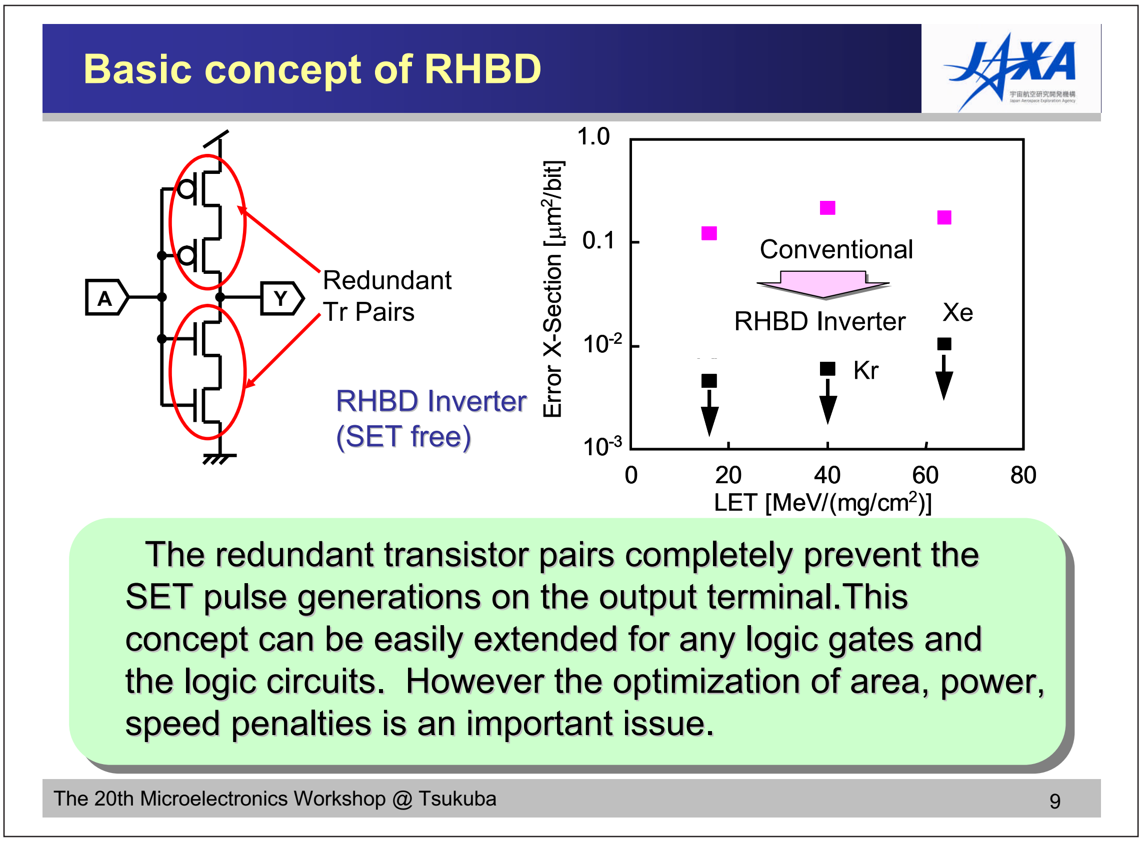
8


Basic concept of RHBD
JAXA
A
Y
Redundant Tr Pairs
RHBD Inverter (SET free)
Error X-Section [μm^2/bit]
1.0
0.1
10^{-2}
10^{-3}
Conventional
RHBD Inverter
Xe
Kr
0
20
40
60
80
LET [MeV/(mg/cm^2)]
The redundant transistor pairs completely prevent the SET pulse generations on the output terminal.This concept can be easily extended for any logic gates and the logic circuits. However the optimization of area, power, speed penalties is an important issue.
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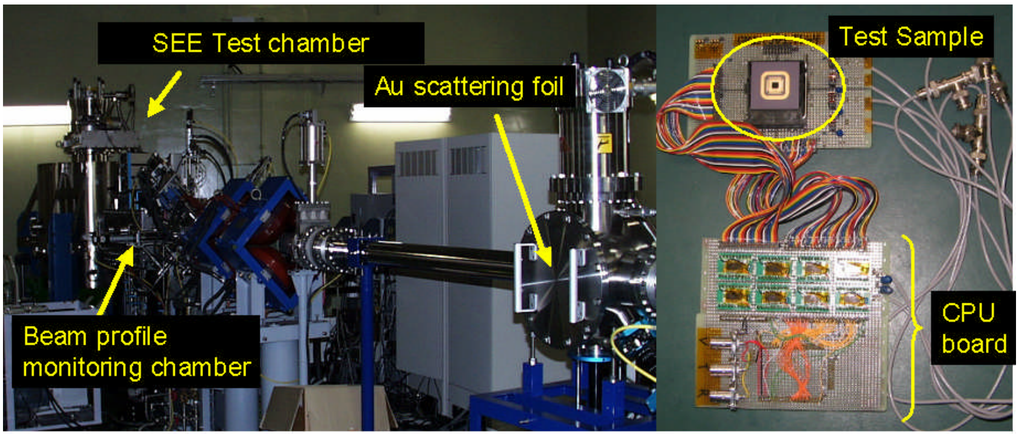
9

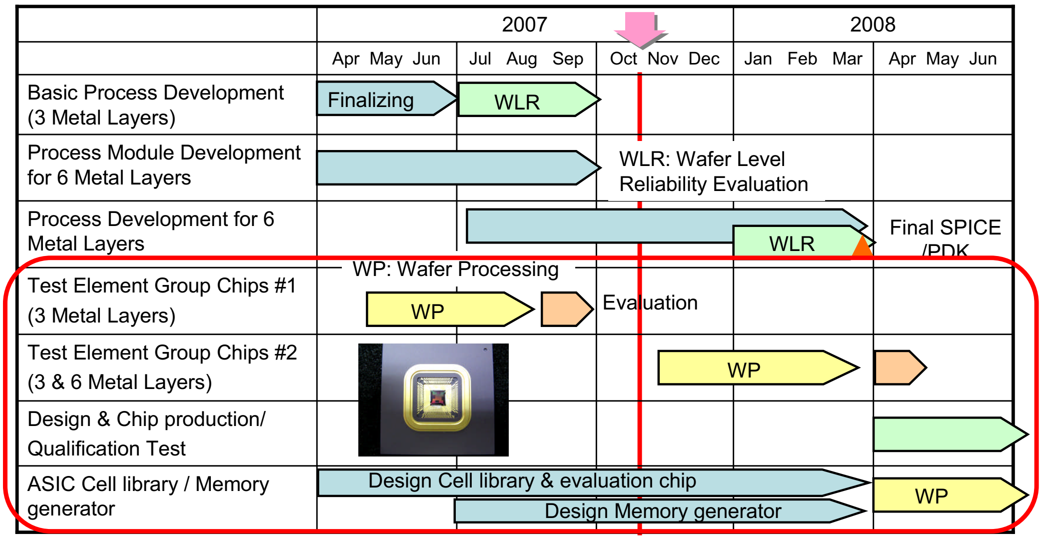
TEG evaluation

The design and evaluation (Irradiation test) of the Test Element Group are in progress.Test results will be applied to the design of FPGA and Cell library.



Irradiation test system (Heavy-ion accelerator at Japan Atomic Energy Agency)

Development schedule (ASIC & FPGA)



Test Element Group Chips #1
Configuration bits / Free RAMs for FPGA
RAM cells, Shift registers for SET testing

Test Element Group Chips #2
Core cells for FPGA

Radiation Hardened 350nm Triple-Well Mixed-Signal ASIC Technology

° Shin Hisano, David Kerwin, Craig Hafer

Aeroflex Colorado Springs, Inc.
4350 Centennial Boulevard
Colorado Springs, Colorado 80907
USA
www.Aeroflex.com/RadHardASIC

Outline

- Overview of 350nm (0.35μm) CMOS Technology
- Radiation Results
  - Total Ionizing Dose (TID)
  - Single Event Latch-Up (SEL)
  - Single Event Gate Rupture (SEGR)
  - Single Event Upset (SEU)
  - Dose Rate Upset
  - Dose Rate Survivability
- RadHard A-D Converter (ADC) Product Performance
  - Linearity & Noise
- Summary

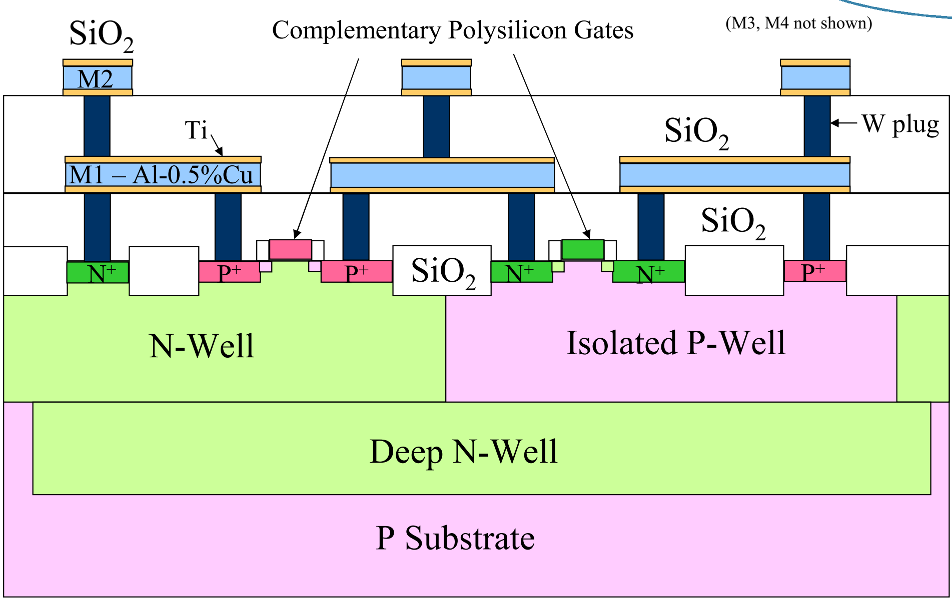
350nm (0.35μm) CMOS Technology

AEROFLEX

- Triple-Well Structure
- 4 Levels of Al-0.5%Cu Metal with barrier metal top and bottom
- Tungsten plugs
- CMP Planarization on each level
- Stacked contacts/vias
- Complementary polysilicon (surface MOSFET)
- Salicide process
- Dual Gate (3.3V and either 5.0V or 10.0V)
- All devices may occur in Deep N-Well

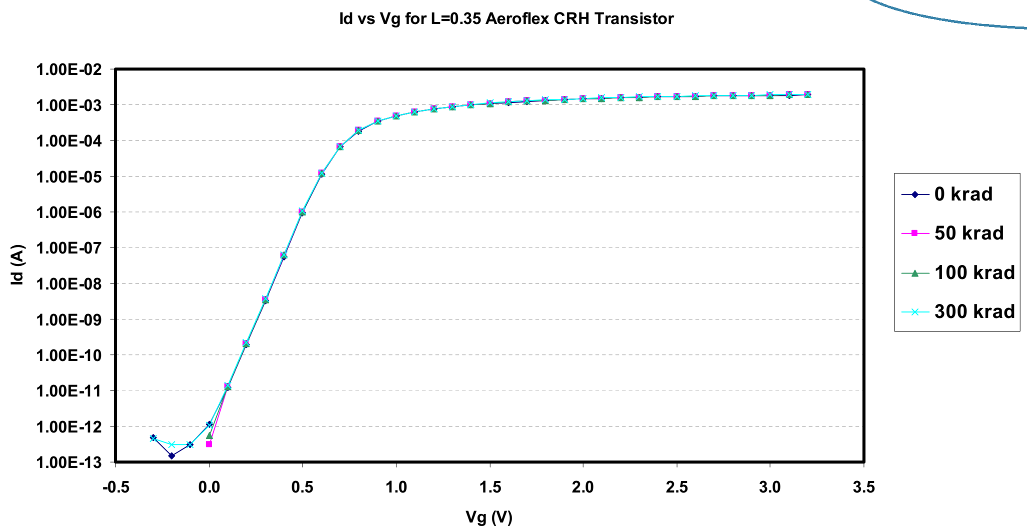
350nm (0.35μm) CMOS Technology

AEROFLEX



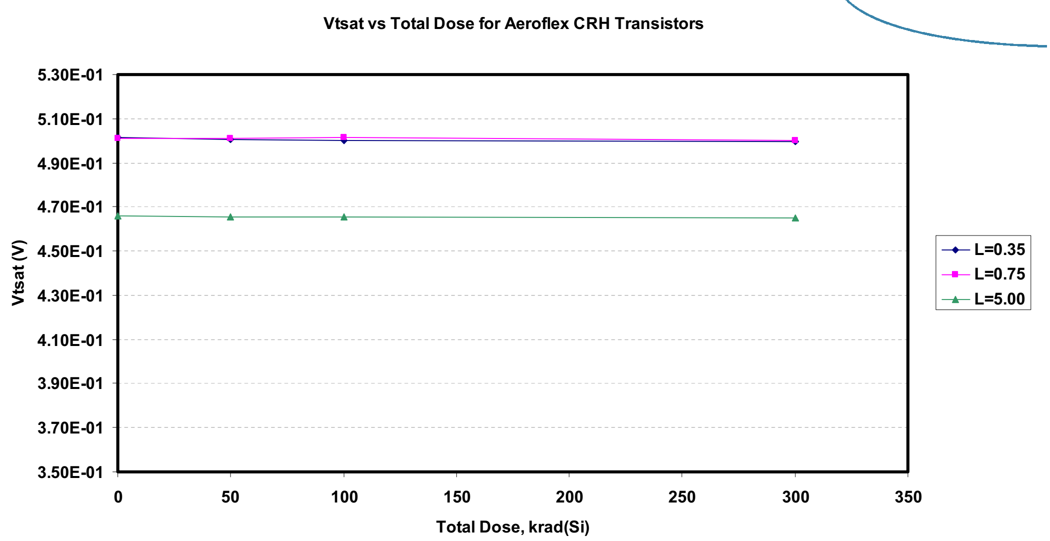
TID: No change after 300krad (Si)

AEROFLEX

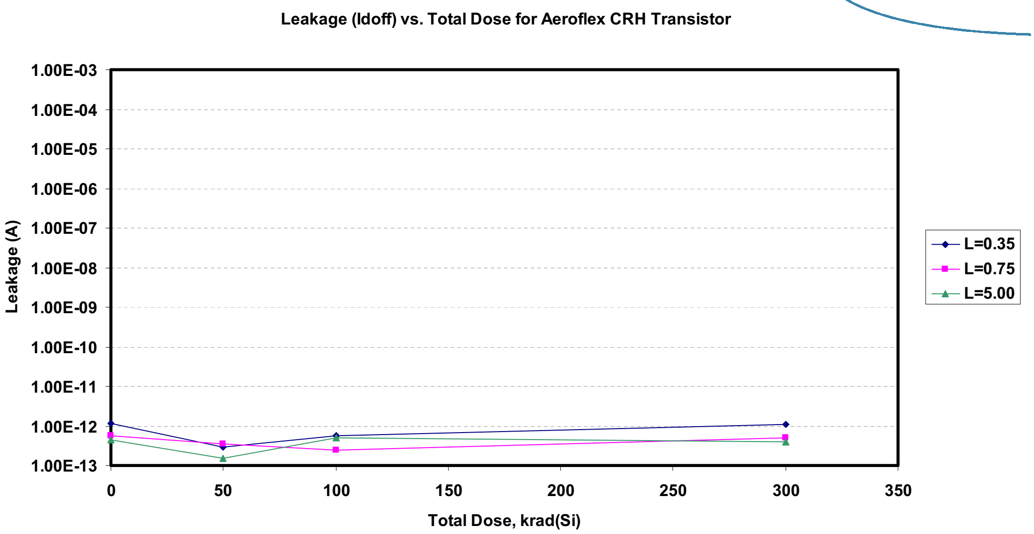


TID: ~2mV Shift after 300krad (Si)

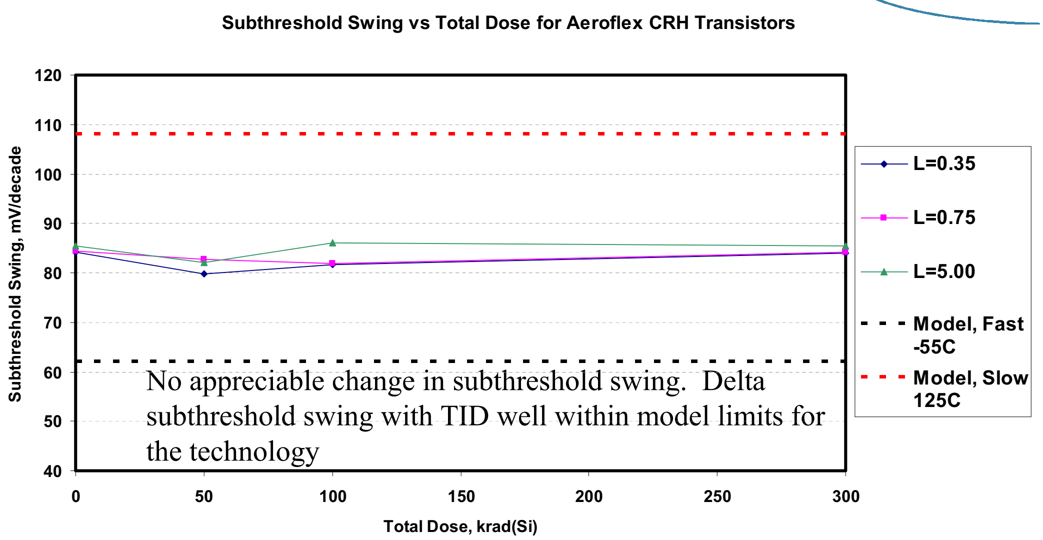
AEROFLEX



TID: No leakage after 300krad (Si)

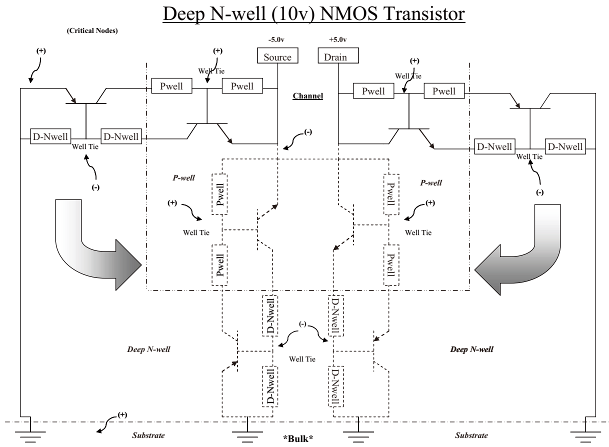


TID: Subthreshold Swing Stable after 300krad (Si)



SEL Test Structure

AEROFLEX



SEL

AEROFLEX

- **Test 1 (3/26/06):**
  - Test structures irradiated with Xe ions at an equivalent LET of 113 MeV-cm^2/mg to a total fluence of 1E7 ions/cm^2 at a temperature of 125° C, maximum Vdd (10V)
  - Test Structure Area = 20,000 sq. microns with 1,000 sq. microns of sensitive active area.
    - Total of 100 ion hits in sensitive area during test, with total of 2000 ion hits in entire structure
  - Results: No SEL was observed on any structure (6 test structures)

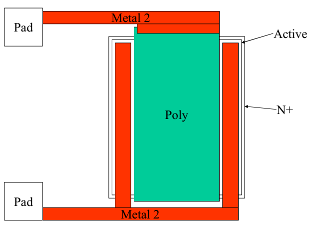
SEL

- **Test 2 (4/24/06):**
  - Test structures irradiated with Xe ions at 60° angle for an equivalent LET of 113 MeV-cm^2/mg to a total fluence of 1E7 ions/cm^2 at a temperature of 125° C, maximum Vdd (10V)
  - Results: No SEL was observed on any structure (6 test structures)
- **Test 3 (7/12/07):**
  - ASIC containing ~30k gates and 17 ADC channels irradiated with Xe ions at 60° angle for an equivalent LET of 113 MeV-cm^2/mg to a total fluence of 1E7 ions/cm^2 at a temperature of 125° C, maximum Vdd (5.5V)
  - Results: No SEL was observed in the ASIC (4 devices tested)

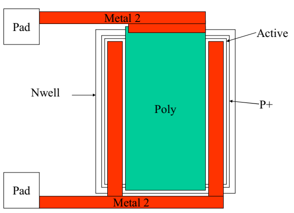
SEGR

- **Test (3/26/06):**
  - SEGR testing on structures #13,14 (large area N-ch and P-Ch thin gate oxides).
  - Irradiated with Xe at angle of 60° for an effective LET of 113 MeV cm^2/mg at bias voltages of 3.6V, 5V and 15V.
  - Results: The structures did not break down.

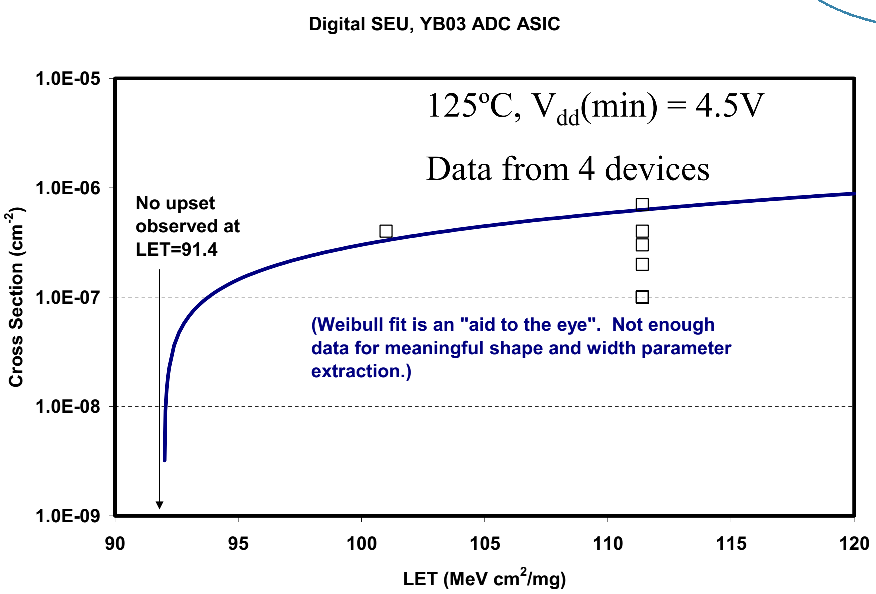
13) Conventional Nch with guard ring



14) Conventional Pch with guard ring



SEU

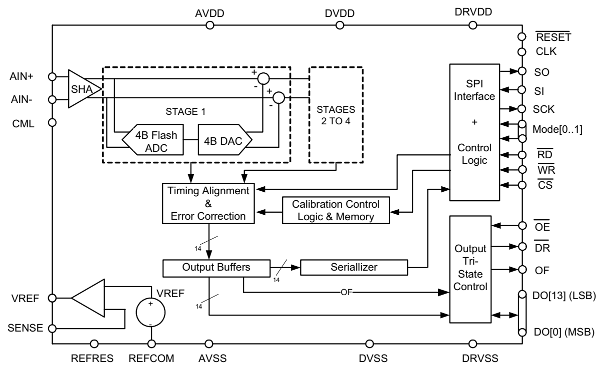


Dose Rate

- Testing performed at Boeing Radiation Effects Laboratory (BREL) FXR-75 Flash X-Ray Source
- ASIC device exposed to 35 nsec pulses of x-rays with varying amplitude (varying dose rate)
- ASIC device powered with minimum Vdd (3.0V digital, 4.5V analog) for upset testing
- First digital upset at 6.0×10^9 Rad(Si)/sec
- ASIC device powered with maximum Vdd (3.6V, 5.5V analog) for latch-up testing
- No latch-up observed at highest achievable dose rate of 1.1×10^{11} Rad(Si)/sec

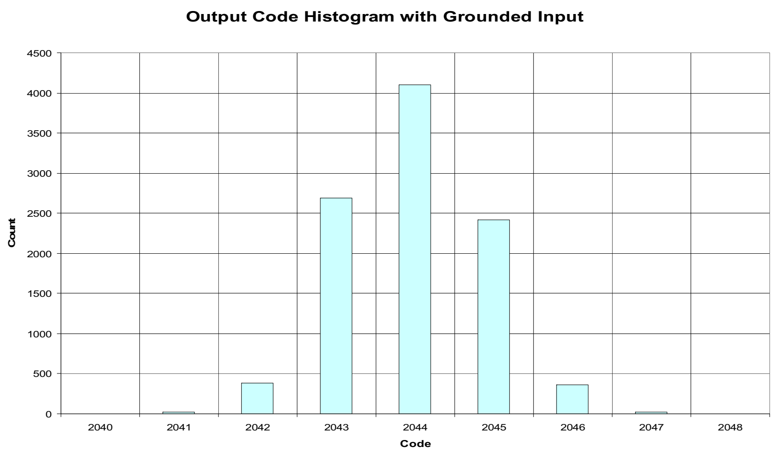
RadHard A-D Converter (ADC) Overview

- 12-bit, 2.5MSPS, Pipeline ADC with On-Chip Calibration
- 3.3V Supply, 20mW



RadHard A-D Converter (ADC) Performance

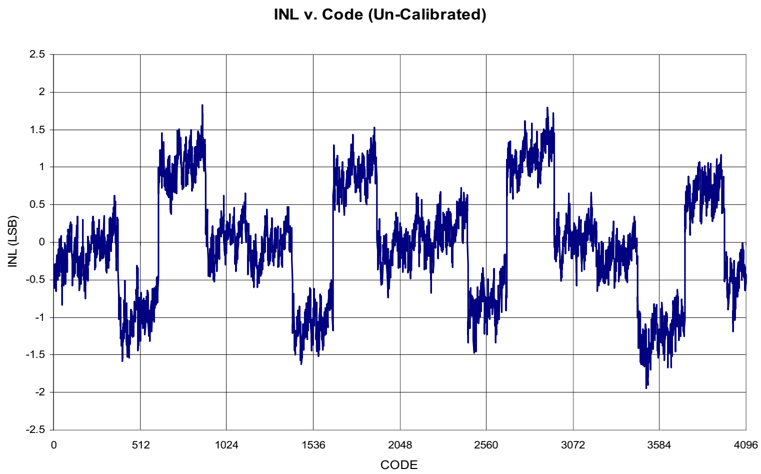
- Noise – 0.92 LSB_{RMS} (Includes Internal Trans-Impedance Amp)



RadHard A-D Converter (ADC) Performance

AEROFLEX

- INL before Calibration @ 2.5Msps < +/- 2 LSBs



Summary

AEROFLEX

- Aeroflex has developed Commercial RadHard™ Mixed-Signal ASIC library on 350nm (0.35μm) Triple-Well CMOS
  - Excellent radiation hardness results
    - 300krad (Si)
    - SEL immune
    - Excellent SEU performance
- Aeroflex 12-bit pipeline RadHard A-D Converter (ADC) tested
  - Linearity: INL < +/- 2 LSB
  - Noise < 0.92 LSB_{RMS}

MITSUBISHI 三菱電機 *Changes for the Better*

Development of Low Shock Release Device

2007.10.30

○Takao Matsui, Jun Nakagawa(MELCO)
Hiroshi Miyaba(JAXA)

MITSUBISHI 三菱電機 *Changes for the Better*

Needs

【Development Point】

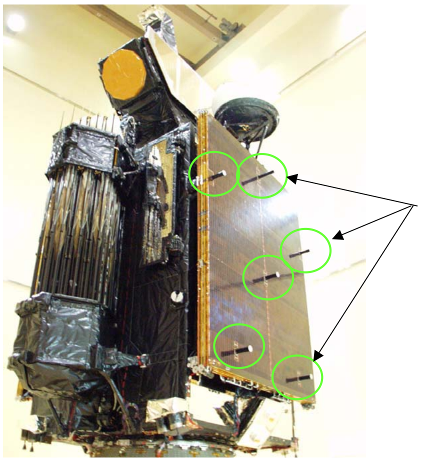
・The high shock of conventional pyrotechnic Lock Release Device constrains onboard hardware arrangement.

・Improvement is demanded to enforce competitiveness of our satellite products.

⇒ Development of Low Shock Release Device(LSRD) is necessary.

【Development Goal】

・The conventional pyrotechnic lock release device produces over 1,000(X9.8 m/s^2 srs){Gsrs}. We aim less than 100(X9.8 m/s^2 srs){Gsrs} shock output.

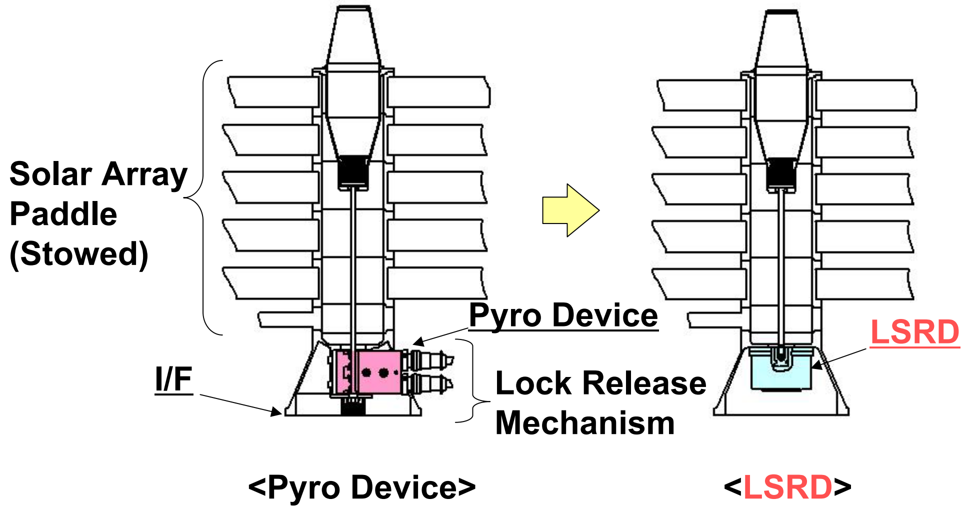


1

MITSUBISHI 三菱電機

Pyro Compatibility

Changes for the Better



2

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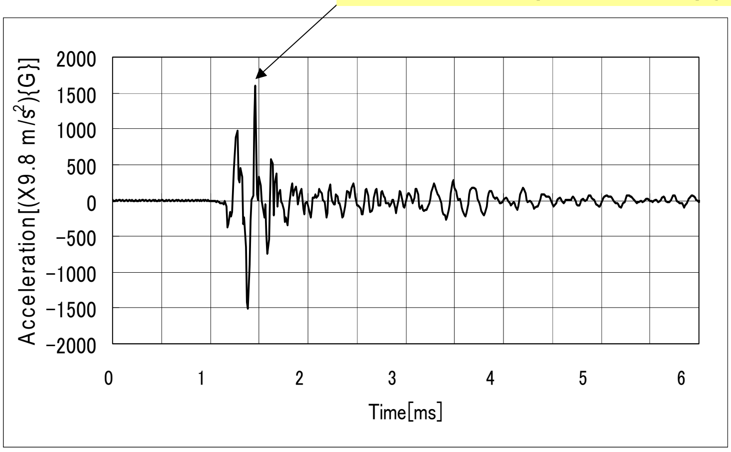
Pyro Shock-Time History

Changes for the Better

High shock of conventional pyrotechnic Lock Release Device

about 1,600(X9.8 m/s^2){G} max



Preload: 7.35kN
Test was performed on aluminum plate:
230X230X20mm
Measured: 57mm from source

Example of Pyroshock Acceleration Time History

3

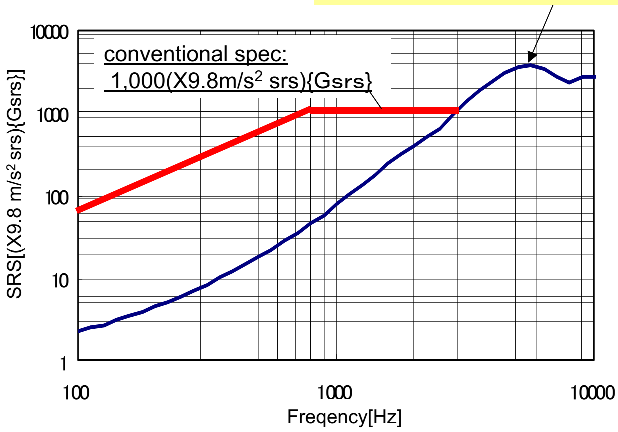
MITSUBISHI 三菱電機

Pyro Shock-SRS

Changes for the Better

High shock of conventional pyrotechnic Lock Release Device

about 4,000(X9.8 m/s² srs){Gsrs} max



Preload: 7.35kN
Test was performed on aluminum plate:
230X230X20mm
Measured: 57mm from source

Example of Pyroshock SRS

SRS: Shock Response Spectrum

4

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LSRD Overview

Changes for the Better

Objective:
- ●Reduction of lock release shock
  - ⇒Relaxation of constraints of onboard hardware

Impact shock:
- ●Low Shock Release Device:100 (X9.8 m/s² srs){Gsrs}
- ●Pyrotechnic lock release device : 1,000 (X9.8 m/s² srs){Gsrs}

Application:
- ●Lock and release device for Solar Array Paddle
- ●Lock and release device for optical instruments

Challenge:
- ●Originality of the mechanism
- ●High reliance
- ●Cost competitiveness
- ●Interface compatibility with conventional device
- ●Reuse operation capability

Outside View of LSRD

5

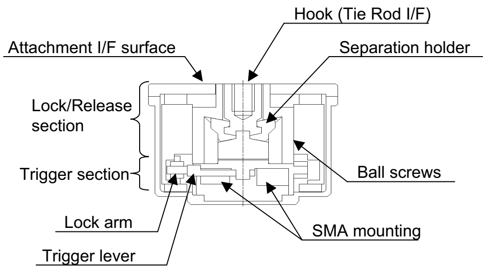
MITSUBISHI 三菱電機

LSRD Spec

Changes for the Better

- LSRD(Prototype) development specification

Load retention/Release system	Ball screw + Separation holder
Trigger system	SMA (Shape Memory Alloy)
Lubricant system	Solid lubrication
Retention load	10kN
Shock output	100 (X9.8 m/s^2 srs){Gsrs}
Dimension	Smaller than ϕ60×50mm (body only)
Mass	Less than 350g
Trigger signal	Pyrotechnic I/F compatible
Operation time	Less than 200ms
Temperature	Op/Non-Op –55℃ ～ +70℃
Operation endurance	More than 100 times of operation.
Redundancy	Redundant trigger electrical system
U.S.A. EL/TAA concern	Completely free.



<Apparatus gross outline (cutaway view)>

MITSUBISHI 三菱電機

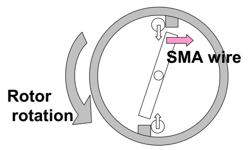
Mechanisms

Changes for the Better

Operation principle

・Release the link structure by energizing and heating the SMA wire in the Trigger structure. By the upper displacement of the ball screw, the Separation holder moves up to unhook the Rod.

1. Releasing lock and Beginning of Separation.



Beginning of separation

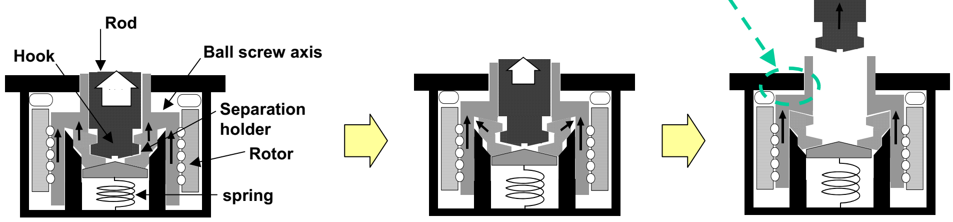
2. Unloading the rod axial force

3. Unleashing the Separation holder

4. Releasing the Hook

5. Stopping of rotor rotation, then completing its separation

The axis of the ball screw stops as it reaches the case. The Rotor stops its rotation.



MITSUBISHI 三菱電機

LSRD Shock test

Changes for the Better

Shock test configuration: Long Rod Case

8

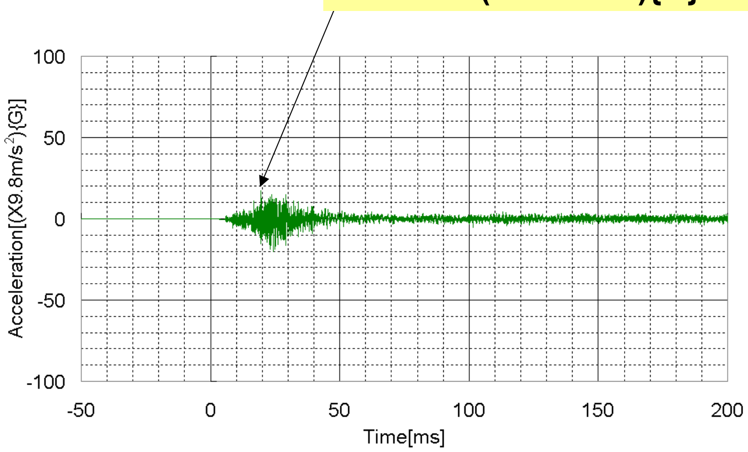
MITSUBISHI 三菱電機

LSRD Shock-Time History

Changes for the Better

Negligible Low Shock of LSRD

about 20 (X9.8 m/s²){G} max



Preload: 10kN
Test was performed on aluminum plate: 530X530X5mm
Measured: 54mm from source
Configuration: Long rod

Example of LSRD(Prototype) Acceleration Time History

9

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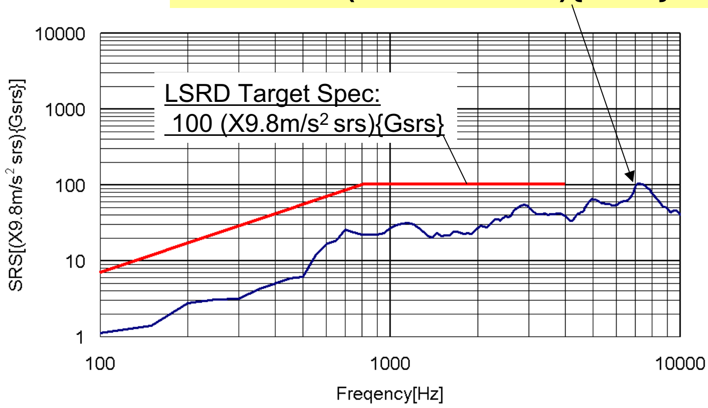
LSRD Shock-SRS

Changes for the Better

Negligible shock of LSRD

about 100 (X9.8 m/s² srs){Gsrs} max



Example of LSRD(Prototype) SRS

Preload: 10kN
Test was performed on aluminum plate: 530X530X5mm
Measured: 54mm from source
Configuration: Long rod

10

MITSUBISHI 三菱電機

Schedule

Changes for the Better

- ✓Feasibility has been confirmed in program JFY04,05(Joint research with JAXA) .
- ✓Development phase has been started as JFY06 JAXA standard component.
- ✓Preliminary Design Review was completed in February 2007.
- ✓It is in critical designing phase, now.
- ✓Qualification tests is planned to complete in JFY08.

	2004	2005	2006	2007	2008	2009
JAXA joint research	→	→				
JAXA standard component development			Preliminary design	Critical design	Update design	

Schedule

11

National Aeronautics and Space Administration

The Development of a NASA Lead-free Policy for Electronics

Lessons Learned

Presentation to the 20th JAXA Microelectronics Workshop (MEWS 20)
Tsukuba, Japan
October 29, 2007

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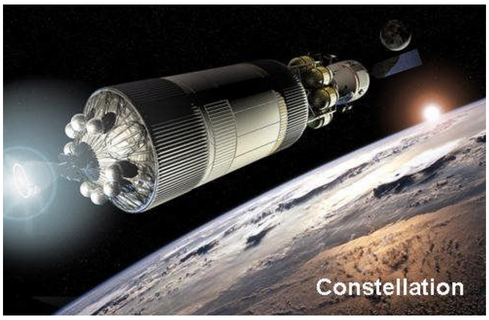
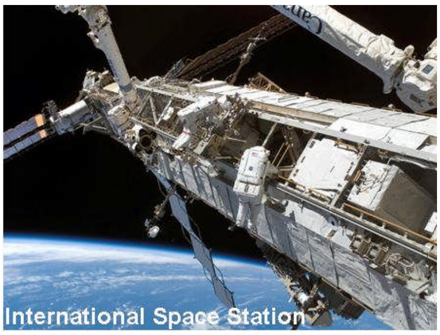
www.nasa.gov

Overview

- Background
- Current Situation
- Making a Policy
- Issues Encountered





NASA Lead-free Involvement

- The NASA EEE Parts and Packaging Program (NEPP) has Maintained the "Tin and Other Metal Whiskers" Website for Almost 10 Years http://nepp.nasa.gov/whisker/
- In Addition, NASA has been an Active Participant in the Tin Whisker and Lead-free Solder Research Activities of:
  - The Joint Group on Pollution Prevention (JGPP)
  - International Electronics Manufacturing Initiative (iNEMI)
  - Center for Advanced Vehicle Electronics (CAVE), Auburn University, Alabama
  - Center for Advanced Life Cycle Engineering (CALCE), University of Maryland
  - GEIA G12, Lead-free subcommittee
  - Lead-free Electronics in Aerospace Project Working Group (LEAP WG)
  - Executive Lead-free Integrated Process Team (ELF IPT)

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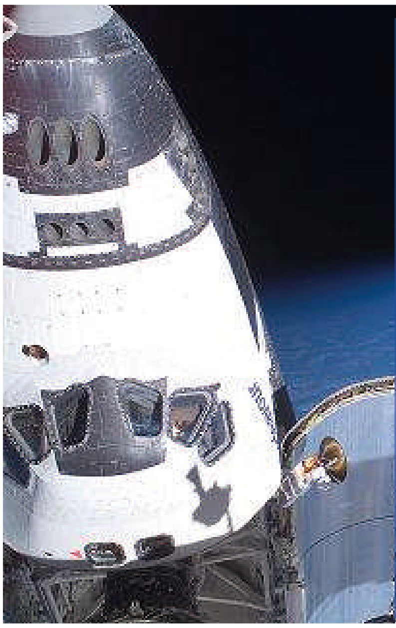
Our Current Situation



- A Comprehensive NASA "Agency Level" Policy for Pb-Free Electronics Does Not Exist Today
- Some Aspects of a Pb-Free Policy are Implied by NASA Workmanship Stds and NASA Field Center Parts Selection Stds
  - Preferred solders such as Sn60 and Sn63
  - Avoidance of pure tin surface finishes
- However, Without a Solid Over - Arching Policy, Errors and Chaos Can be Expected

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Lead-free Electronics in Aerospace Project Working Group (LEAP WG)

- Formed in 2004 as Aerospace Industries Association (AIA) Lead-free Aerospace Electronics Working Group
- Includes All Stakeholders (Market Segments, Supply Chain, Geographic Regions)
- Addresses Issues that are:
  - Unique to aerospace and military
  - Within control of aerospace and military
- Develops Handbooks and Standards for Lead-free Implementation
  - Published through the GEIA, IEC in the Future
- <u>ESA participates but NOT JAXA</u>
- Next Meeting: Irving Texas (BAE) January 30 and 31, 2008

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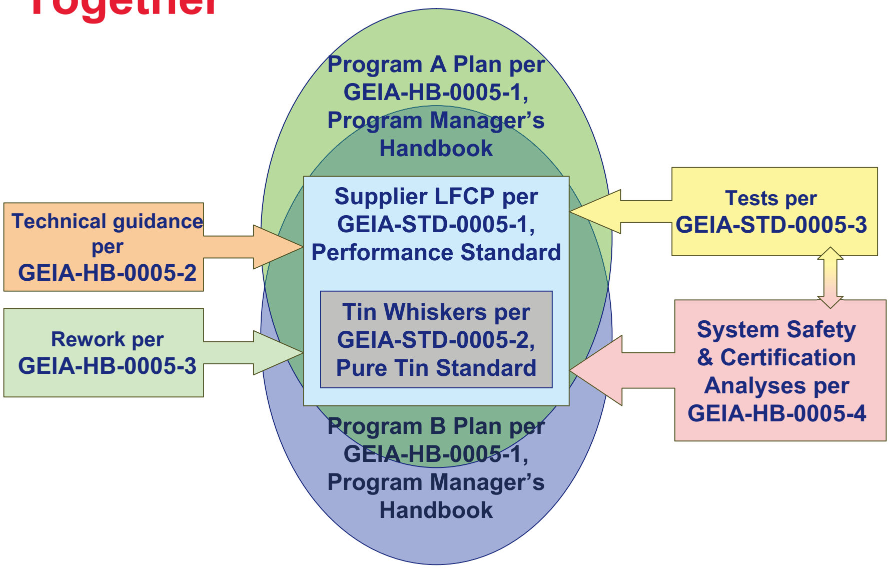
How the LEAP Documents Work Together



LEAP WG Planned Deliverables

Document Number	Title	GEIA Publication
GEIA-HB-0005-1	Program Management/ Systems Engineering Guidelines for Managing the Transition to Lead-free Electronics	2Q 2006
GEIA-HB-0005-2	Technical Guidelines for Aerospace Electronic Systems Containing Lead-free Solder and Finishes	3Q 2007
GEIA-STD-0005-1	Performance Standard for Aerospace and High Performance Electronic Systems Containing Lead-free Solder	2Q 2006
GEIA-STD-0005-2	Standard for Mitigating the Effects of Tin Whiskers in Aerospace and High Performance Electronic Systems	2Q 2006
GEIA-STD-0005-3	Performance Testing for Aerospace and High Performance Electronics Containing Lead-free Solder and Finishes	1Q 2008
GEIA-HB-0005-3	Rework and Repair Handbook for Aerospace and High Performance Electronic Systems Containing Heritage SnPb and Lead-Free Solder and Finishes	1Q 2008
GEIA-HB-0005-4	Impact of Lead Free Solder on Aerospace Electronic System Reliability and Safety Analysis	1Q 2008

Released In ballot

Industry Lead- free Control Plans (LFCPs)

- One Day Workshop Following Recent Meeting of LEAP/ELF IPT in Baltimore
- Well Attended > 60 people Including Several not There for LEAP or ELF IPT
- Very Informative ~6 company Presentations
- All Using GEIA-STD-0005-1 and -2
- All Planning to Offer a Single Corporate Plan
  - If you want more, expect to pay
- Common Themes
  - Overall LFCP per GEIA-STD-0005-1
  - No Pb-free solders except for special applications
  - GEIA-STD-0005-2 Level 2B
    - » Generic part identification, generic mitigation statements

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The "Simple" NASA Policy (Not Yet Approved)

- *Electronics Solders*
  - Require traditional tin-lead solders for all electronic assembly except when justified by technical need (such as a high melt point)
    - » Approved GEIA-STD-0005-1 plan to define rules and controls
    - » SAC and other "new" alloys require special and exceptional rationale
- *Component Surface Finishes*
  - Require Programs to meet GEIA-STD-0005-2, "Control Level 2C". Specific allowances may be given for "Control Level 2B"
    - » 2B – Identification by part type, mitigation description and assessment by part type (ex. ceramic capacitors, conformal coating, all surfaces covered with enough coating to suppress whiskers)
    - » 2C – Identification by individual part, where used, why, mitigation method and why that works; prior approval by customer
  - Require all tin-based platings and protective finishes to have a minimum of 3% Pb content unless:
    - » A persuasive rationale is provided
    - » Tin whisker mitigation strategy supported by data and approved by NASA

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Issues We've Encountered Along the Way

- NASA Document tree?
  - Policy needed for EEE parts but also mechanical parts, materials and processes
- What is PURE tin, or suitably leaded tin?
  - How to measure?
- EEE Parts Built Using Tin-based Pb-free Solders for Years
  - Example high temp Solders (Sn-Ag, Sn-Sb, et al)
  - Acceptance at the part level sets precedent at the board level
  - What about use internal to the part?
  - What do we really know about "whiskers" from these alloys?
- Incoming Surveillance for Prohibited Materials is NOT "Plug and Play"
  - Standard Test Methods are Needed
  - Standard Reference Materials are Needed
  - Operator Training is ESSENTIAL!!!
  - Test labs get inconsistent results

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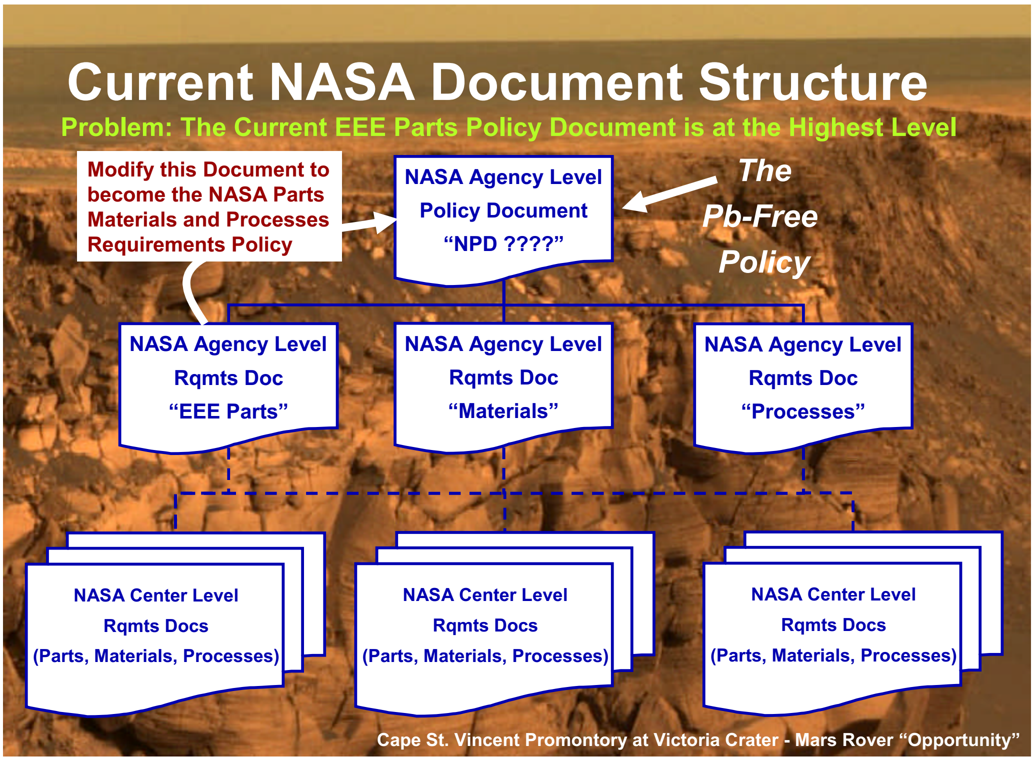

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Determining What is NOT Pure Tin

- Current Specifications and Standards Say <97% Tin
  - NASA wants the other 3% minimum to be Pb
- Measurement Methods are not Precise; They Have a Tolerance
  - If the tolerance is ±3%, then up to 5% actual lead content could fail
  - Raising the limit to 5% or even 10% does not fix the basic problem
  - (Assays showing elemental contents to even one decimal place are bogus, none of the systems in use have this accuracy)
- Granular Structure of Tin-Lead can Lead to Large Variations in Apparent Composition When Illuminated With a Small Spot Size (EDS)
  - Checking multiple sights and averaging can overcome this but might then fail to detect genuine tin rich areas
- Calibration Standards are Needed but Variable Morphology and Aging Effects Make this Difficult
- Meeting September 18, in Los Angeles, Tried to Resolve These Issues
  - Agreed to the >97% Sn, <3% Pb definition of <u>Pure Tin</u>
  - Agreed XRF for quick check, EDS for precision
  - NIST may provide standards including a 97/3 Sn/Pb
- JEDEC JC13.1 has task group developing a standard Pb measurement test method for MIL-STD-750
  - If they succeed it could be used as basis for a general method

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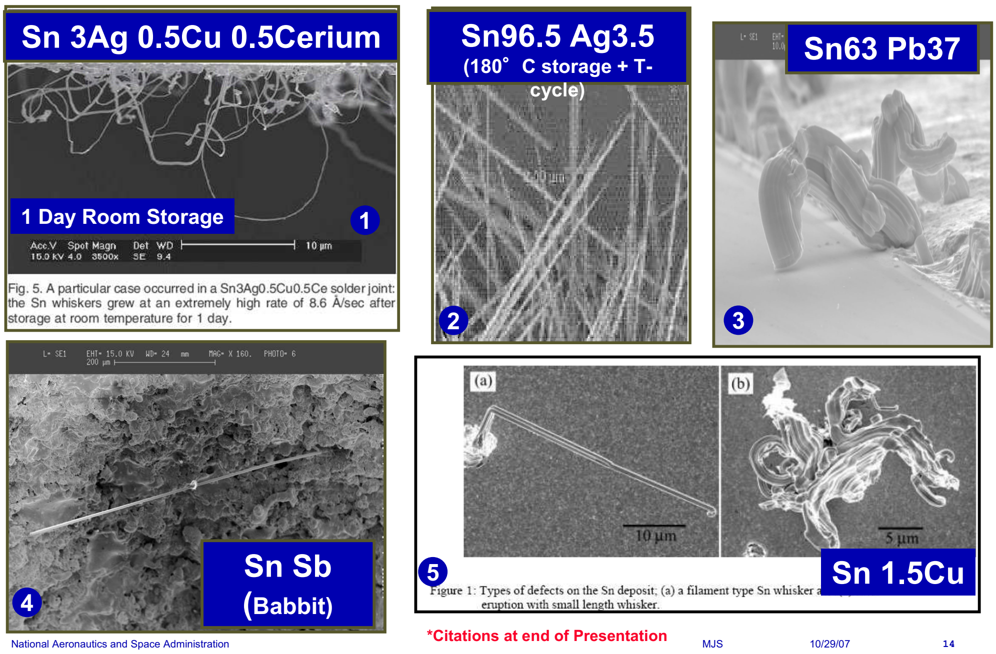
"Some" Tin Alloys that Have Grown Whiskers*



*Citations at end of Presentation

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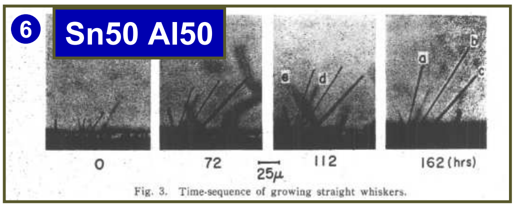
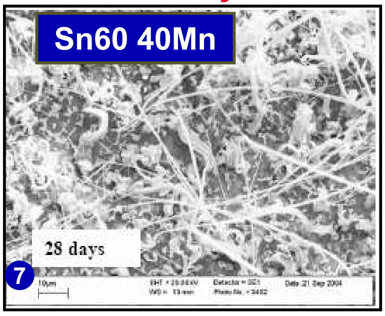
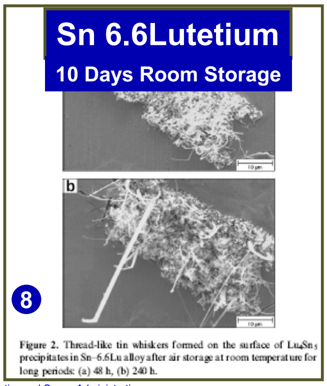
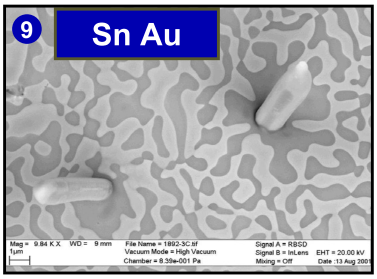
More Tin Alloys that Have Grown Whiskers*

For whisker inhibition it matters what material is alloyed with Sn









*Citations at end of Presentation

*Citations

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5. T. Chuang, et al, "Abnormal Growth of Tin Whiskers in a Sn3Ag0.5Cu0.5Ce Solder Ball Grid Array Package", Journal of ELECTRONIC MATERIALS, Vol. 35, No. 8, 2006
6. N. Asrar, et al, "Tin Whiskers Formation on an Electronic Product: A Case Study", Jrnl Fail. Anal. and Preven. (2007) 7:179–182
7. H. Leidecker, "Whiskers of Sn-Pb on REFLOWED Die Attach Solder Used in the Manufacture of Laser Diode Arrays", December 2003
8. N. Furuta, "Growth Mechanism of Proper Tin Whisker", Japanese Jrnl of App. Phys. Vol. 8, No. 12, December 1969
9. Private Communication – "Whiskers on Au-Sn Solder", R. Ogden – August 2004

Summary of Empirical Evidence for Whisker Growth on Sn Alloys (Not a Complete Listing)

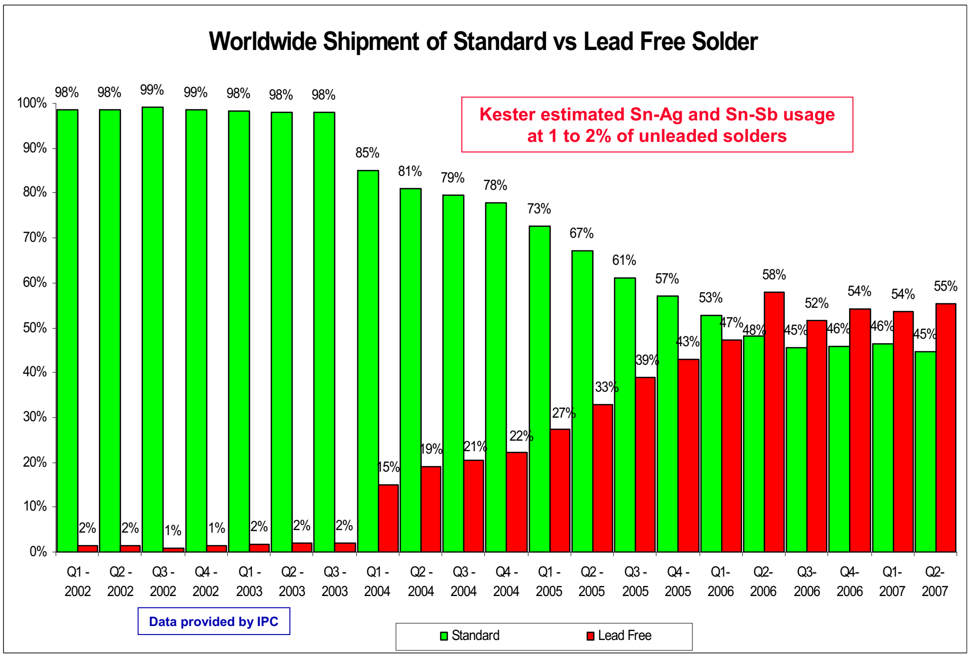
ALLOY	EVIDENCE
1. Sn	Lots of Data – Significant Whisker Tendencies
2. Sn-Pb	Lots of Data – Greatly Reduced Whisker Tendencies
3. Sn-Ag	Minimal data – "Maybe" High Temp Application Makes Worse
4. Sn-Au	A Few Experiences Citing Whiskers
5. Sn-Al	1 Study – Lots of whiskers
6. Sn-Bi	Minimal data
7. Sn-Cu	Some data – increased whisker tendency (SWATCH failures)
8. Sn-Lu	Only 1 Study – Significant Whisker Tendency
9. Sn-Mn	Only 1 Study – Significant Whisker Tendency
10. Sn-Sb-X	Few Observations –Film Caps & High Temp Solder Applications
11. Sn-Ag-Cu	Minimal Data – 1 Field Concern Noted but NOT in Public Domain
12. Sn-Ag-Cu-Ce	Only 2 Studies – Significant Whisker Tendency

Ag = Silver   Al = Aluminum   Au = Gold   Bi = Bismuth   Ce = Cerium

Cu = Copper   Lu = Lutetium   Mn = Manganese   Sb = Antimony   Sn = Tin

National Aeronautics and Space Administration   MJS   10/29/07   17

The Impact of Lead-free on Solder Sales



National Aeronautics and Space Administration   MJS   10/29/07   18

A Few Caveats about Whiskers

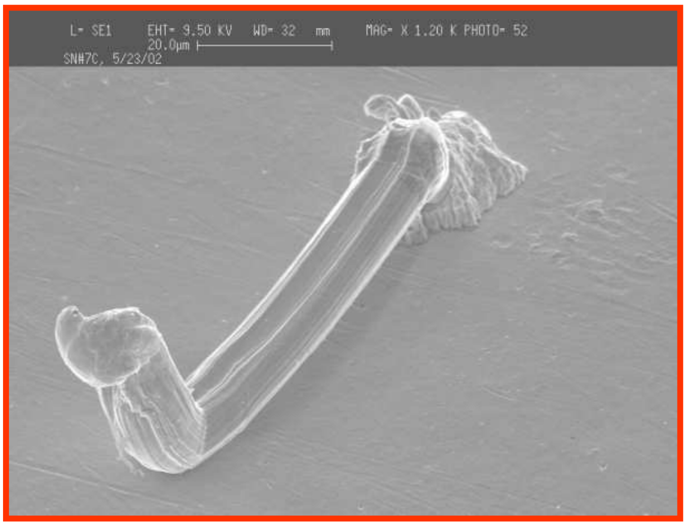
- No One Knows How to Predict Complete Freedom from Tin Whiskers on Tin or Tin Alloy Coatings
  - Ditto for Zinc, Cadmium, and many others
- Current Ideas have Utterly Failed to be Usefully Predictive
  - Present Methods are NOT Predictive of Incubation Time, Rates of Growth, Density of Growths, et al
  - No Known Acceleration Factors
  - No Correlation of Whisker Tendencies in One Environment vs. any Other Environment

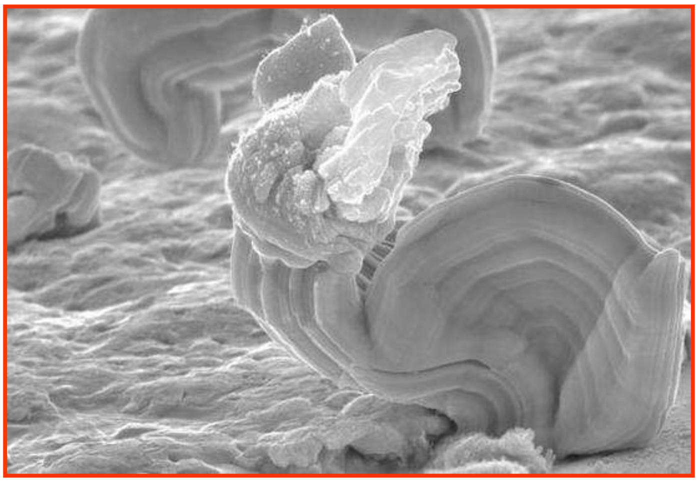
AND

THEY MAY BE AN ALIEN LIFE FORM!

400μm 70X

Whose Bite is Worse?





Cute Whiskers

"Not So" Cute Whiskers

The NASA Electronic Parts and Packaging (NEPP) Program is proud to announce an interim meeting to be held in lieu of MAPLD for 2007. This is a one-year only event.

Military and Aerospace FPGA and Applications (MAFA) Meeting

When: Nov 27th - Nov 29th, 2007
Where: Palm Beach Gardens Marriott
Palm Beach, FL
http://www.marriott.com/hotels/travel/pbipg-palm-beach-gardens-marriott/

Hotel reservation details will be on the MAFA website NLT 10/1 (Gov. Rate of $103/night)

Logistics notes

Registration fee: $0 (free)

Maximum number of attendees: 300 (50 slots will be held for NASA and JPL attendees)
Side meeting rooms will be available throughout each day

The meeting will be held over 3 full days with each day focused on a differing FPGA-related area. The 3 days are:

Industry day: focused on vendor products and roadmaps (in lieu of an industrial exhibit),

Radiation/reliability day: focused on recent results and plans for radiation and reliability related endeavors with FPGAs, and,

Applications day: focused on applications and field experience using FPGAs for military and aerospace systems.

This is an open meeting with US citizenship or green card NOT being required. However, an ITAR-restricted session may be held pending submission contents.

Submissions and registration extended until 10/15/07.

Thank You for Your Attention!!!

National Aeronautics and Space Administration　MJS　10/29/07　23

日本の鉛フリー化の状況

07年10月30日
山本　克己
JEITA実装技術標準化専門委員会副委員長
（テクノオフィス　ヤマモト）

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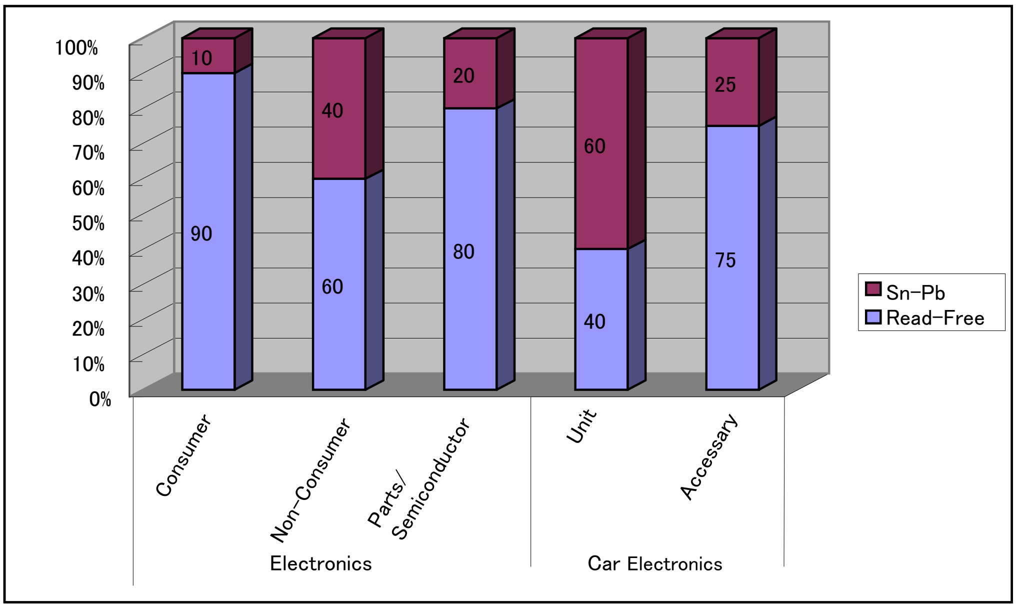
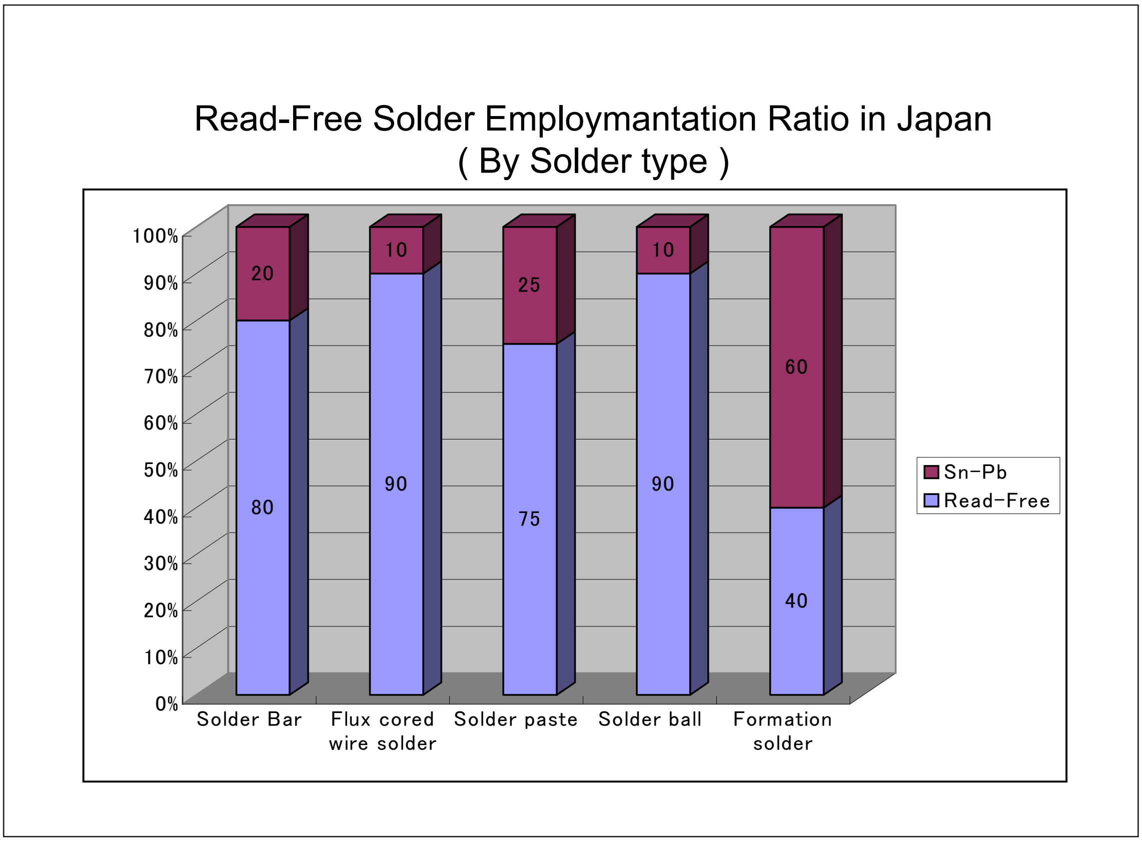
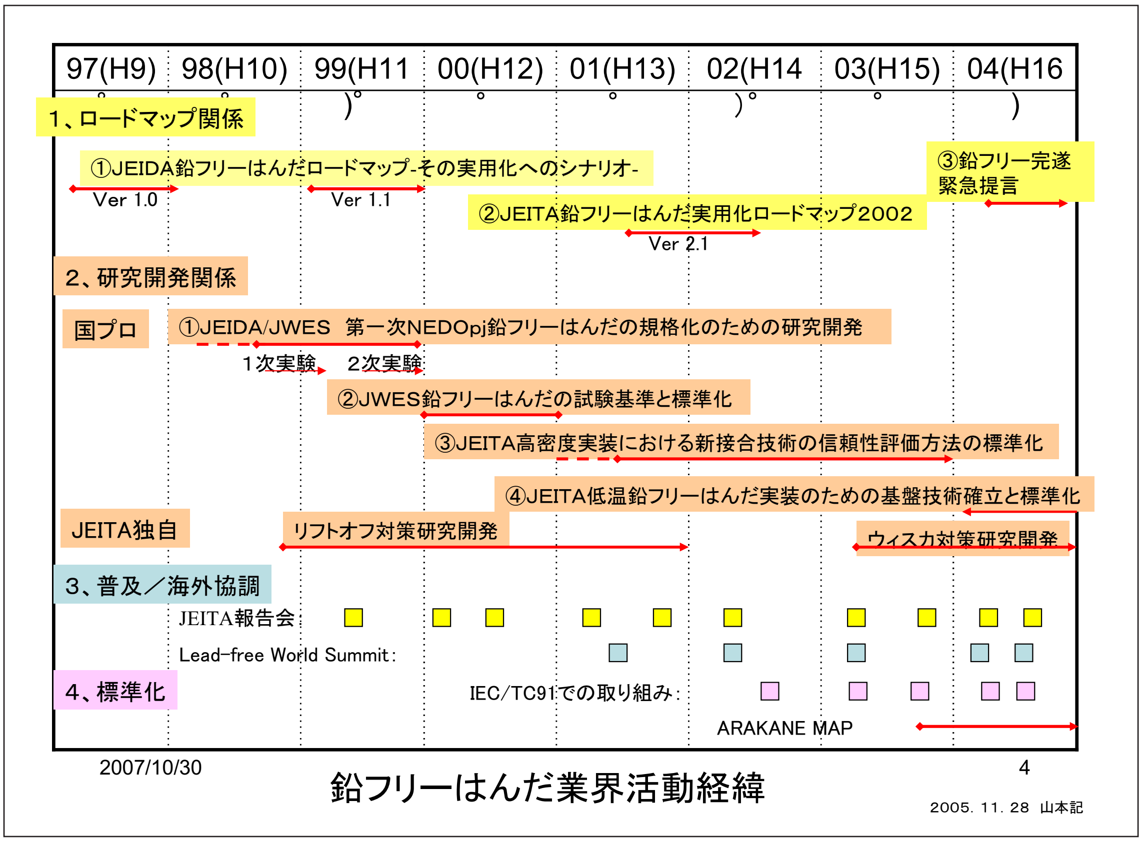
Read-Free Solder Employmantation Ratio in Japan
(Electronics vs Car Electronics)

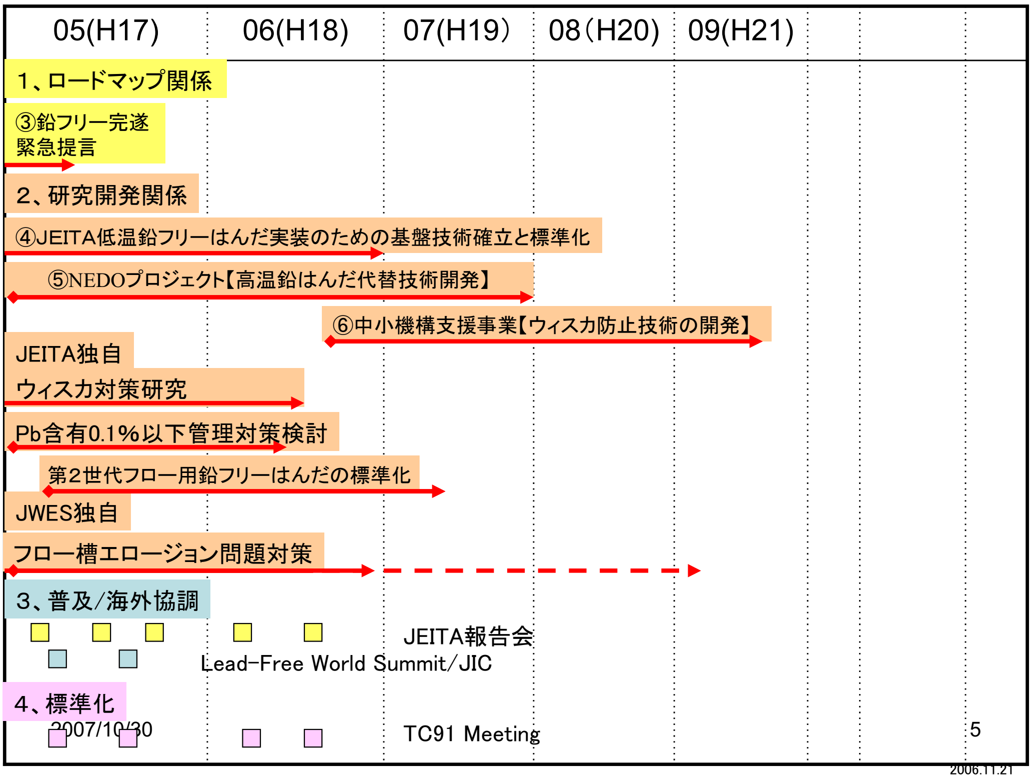




Read-Free Solder Employmantation Ratio in Japan
(By Solder type)
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
20
80
10
90
25
75
10
90
60
40
Solder Bar
Flux cored wire solder
Solder paste
Solder ball
Formation solder
Sn-Pb
Read-Free



97(H9)。
98(H10)。
99(H11)。
00(H12)。
01(H13)。
02(H14)。
03(H15)。
04(H16)
1、ロードマップ関係
①JEIDA鉛フリーはんだロードマップ-その実用化へのシナリオ-
Ver 1.0
Ver 1.1
②JEITA鉛フリーはんだ実用化ロードマップ2002
Ver 2.1
③鉛フリー完遂
緊急提言
2、研究開発関係
国プロ
①JEIDA/JWES 第一次NEDOpj鉛フリーはんだの規格化のための研究開発
1次実験
2次実験
②JWES鉛フリーはんだの試験基準と標準化
③JEITA高密度実装における新接合技術の信頼性評価方法の標準化
④JEITA低温鉛フリーはんだ実装のための基盤技術確立と標準化
JEITA独自
リフトオフ対策研究開発
ウィスカ対策研究開発
3、普及／海外協調
JEITA報告会:
Lead-free World Summit:
4、標準化
IEC/TC91での取り組み:
ARAKANE MAP
2007/10/30
4
鉛フリーはんだ業界活動経緯
2005. 11. 28 山本記



Challenges and Efforts Toward Commercialization of Lead-free Solder

Roadmap 2000 for Commercialization of Lead-free Solder

鉛フリーはんだ実用化に向けた課題と取り組み
鉛フリーはんだ実用化ロードマップ2000
Ver. 1.3

August 2000
R&D Committee for Lead-Free Soldering
鉛フリーはんだ研究開発専門委員会
JEIDA
社団法人　日本電子工業振興協会

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第３章 鉛フリーはんだ合金の選択と導入

フロー、リフロー、糸はんだを含めて、現時点で、実用化の対象として検討されている鉛フリーはんだ合金を以下にまとめてみた。実際の導入に対しては、それぞれ表に示した留意点を考慮する必要がある。また、これら鉛フリーはんだ合金の実装性や信頼性を十分に把握するために、万人に共通とするべきデータベースを構築する必要がある。

表３・１ 鉛フリーはんだ合金リスト

プロセス		合金種類（単位は wt%）	コスト・性能面から、特に採用される傾向にある組成	留意点
フロー		Sn-3.5Ag		Sn-Pb 部品めっきによるリフトオフ，基板ダメージなどには注意すること．
		Sn-(2-4)Ag-(0.5-1)Cu	Sn-3Ag-0.5Cu	
		Sn-0.7Cu に微量元素（Ag, Au, Ni, Ge, In 等）を添加した合金。		
リフロー	中高温系	Sn-3.5Ag		Sn-Ag 系の融点高温化に伴うリフロー温度管理には留意すること．
		Sn-(2-4)Ag-(0.5-1)Cu	Sn-3Ag-0.5Cu	
		Sn-(2-4)Ag-(1-6)Bi，およびこれに In を 1-3 %添加した合金		Bi を数%以上含む場合，Sn-Pb めっき部品との適合性には注意が必要．
		Sn-(8-9)Zn-(0-3)Bi	Sn-8Zn-3Bi	Sn-Zn 系は特殊な腐食環境への適用は注意を要する．また Cu 電極に対しては高温環境では Ni/Au などのバリアめっきをすることが望ましい．
	低温系	Sn-(57-58)Bi	Sn-57Bi-1Ag	Sn-Pb めっき部品との適合性には注意が必要．
手付け・ロボット（糸はんだ）		Sn-3.5Ag		異種のはんだ組成のリペアには適合性に注意すること．
		Sn-(2-4)Ag-(0.5-1)Cu	Sn-3Ag-0.5Cu	
		Sn-0.7Cu に微量元素（Ag, Au, Ni, Ge, In 等）を添加した合金。		

第４章 鉛フリーはんだ導入のロードマップ

これまでの議論および調査をふまえて、鉛フリーはんだ導入のロードマップを作成した。ただし、これはあくまで鉛フリーはんだロードマップであり、鉛フリー化の完遂を予想するものではない。

しかし、我が国の毎年の電気製品の廃棄状況及び産業廃棄物処理場がすでに逼迫している状況を鑑みれば、積極的に実現することが望ましい。鉛フリーはんだの実現には、現時点で見られるようにリフローはんだがフローはんだに先行する。これは、フローはんだにおけるリフトオフの問題が鉛フリーはんだメッキ部品の拡大を待たなければ難しいこと、部品や基板の耐熱性改善が必要とされるためであり、部品や基板サプライヤーの対応が促進される環境の整備が急がれる。

量産品のへの鉛フリーはんだの導入 ・・・・・・・・・・・・・・・・・・・・・・	1999
鉛フリー電極部品の採用開始 ・・・・・・・・・・・・・・・・・・・・・・・・・・	2000
フローはんだプロセスへの鉛フリーはんだ導入 ・・・・・・・・・・・・・	2000
鉛フリー電極部品の採用広がる ・・・・・・・・・・・・・・・・・・・・・・・・・	2001
新製品への鉛フリーはんだの採用が拡大する ・・・・・・・・・・・・・	2001
新製品への鉛フリーはんだ採用が一般的となる ・・・・・・・・・・・・	2002
新製品への鉛フリーはんだ全面採用 ・・・・・・・・・・・・・・・・・・・・・・	2003
鉛入り従来はんだの使用は例外となる ・・・・・・・・・・・・・・・・・・・・	2005

NEDO委託事業（’98～’99）『鉛フリーはんだ規格化のための研究開発』での結論

- 現行めっき（Sn－Pb）部品と実用化候補鉛フリーはんだの組み合わせでは、はんだのBiの含有量が多くなるにつれて接合信頼性が低下する。
- 鉛フリーめっき部品と実用化候補鉛フリーはんだ及び現行はんだ（Sn－Pb）との組み合わせでは、試験結果にバラツキはあるが、顕著な問題はない。
- はんだ付け性に関しては、概ね良好なぬれ性が確保されている。なお、Snめっき品は、安定的なぬれ性を確保できる温度が高くなる傾向にある。

実用化候補鉛フリーはんだ
- Sn－3. 5Ag－0. 7Cu
- Sn－2Ag－3Bi－0. 75Cu
- Sn－2Ag－4Bi－0. 5Cu－0. 1Ge
- Sn－3Ag－5Bi－0. 7Cu
- Sn－3. 5Ag－6Bi
- Sn－0. 7Cu
- Sn－37Pb（Reference）

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Lead-free Roadmap 2002

Roadmap 2002 for Commercialization of Lead-free Solder

機器と部品の連携
鉛フリーはんだ実用化ロードマップ2002
Ver. 2.1

September 2002

Lead-Free Soldering Roadmap Committee
鉛フリーはんだ実用化ロードマップ作成委員会
Technical Standardization Committee on Electronics Assembly Technology
JEITA
Japan Electronics and Information Technology Industries Association
社団法人　電子情報技術産業協会

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1．鉛フリーの定義

鉛フリーの定義：下記のそれぞれの区分において、鉛フリー化すべき所定の部位のPb含有量を0.1w%未満とする。この値を越える場合は、それを明記する。また、特定の除外品を含む場合には、その品目ならびにPb含有量を明記したうえで、それ以外の部位を指すものとする。

部品

- Phase 1　鉛フリーはんだ対応部品：鉛フリーはんだ実装に対応するはんだ耐熱性があるもの。
- Phase 1A　鉛フリーはんだ部品：モジュール部品等で機器のPhase1に相当する部品
- Phase 2　鉛フリー端子部品：部品の基板などへの取り付け端子部のめっき・電極に鉛を含まない。部品の構成部品･材料に鉛が含まれていてもよい。
- Phase 3　鉛フリー部品：内部接続及び/又は構成部品･材料の全ての部位に鉛を含まない。

機器

鉛フリー化機器共通：ボード実装の段階で，基板表面処理，はんだ印刷，はんだ浴などの接続材料に鉛入りはんだを使用しない。

- Phase 1　鉛フリーはんだ機器Ａ：従来部品ないしは鉛フリー対応部品Phase1を使用（実装はんだは鉛フリーであるが、それ以外の構成部品・材料に鉛を含む）
- Phase 2　鉛フリーはんだ機器Ｂ：鉛フリー端子部品Phase2ないしは鉛フリー部品Phase3を使用（実装部品が鉛フリー部品であっても、それ以外の構成部品・材料に鉛を含む場合がある）
- Phase 3　鉛フリー機器：鉛フリー部品Phase3のみを使用し、かつ、実装部品・接続材料以外の構成部品・材料に鉛を含まない
- Phase 0　鉛フリー部品機器：鉛フリー端子部品Phase2ないしは鉛フリー部品Phase3を使用するが、接続材料に鉛入りはんだを使用。鉛フリー化機器の範疇外。

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2．ヨーロッパの鉛規制については環境のためであれば甘受する。その場合は、国内においても同様の規制を求める。

鉛フリー化の定義と判断基準の国際的な合意を急ぐ必要がある。

3．鉛フリー化のマイルストーン：平均的メーカーに対して、下記のスケジュールを設定する。

部品：鉛フリー対応部品／鉛フリー端子部品の供給開始：2001年末
　　鉛フリー端子部品の品揃え完了：2003年末
　　鉛フリー部品の品揃え完了：2004年末
機器：鉛フリーはんだの導入開始：2002～2003年
　　新製品への鉛フリーはんだ全面採用：2003年末
　　鉛フリー化完了：2005年末

「先導メーカー」ではこれより1年先行し、「後続メーカー」では2年遅れとなる。

なお、世界と連携したマイルストーン、ワールドロードマップを設定する必要がある。

4．ボード実装用鉛入りはんだと鉛フリー端子部品の組合わせ実装（機器区分「Phase 0」の存在）

鉛フリー化の遷移段階として、鉛入りはんだを用いて鉛フリー端子部品を実装する場合(Phase 0)を許容する。

部品メーカーにとっては、鉛フリー端子部品と鉛入り部品の両方を準備をしなければならず、部品メーカと機器メーカの連携により、この期間の短縮が必要である。

5．生産拠点の海外移転、部品の海外調達、技術の海外移転に対応した鉛フリー化を推進する。

機器：2002～2003年にかけて海外技術移転を推進、海外協力工場へ積極的な技術供与
　　海外工場については、遅くとも1年遅れの対応を要求
　　購買品、調達品については、即対応を要求
部品：海外工場については、遅くとも1年遅れの対応を要求
　　後続メーカーへの対応／支援が必要である

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６．鉛フリーはんだの標準化：下記のはんだを推奨する。部品電極、端子めっきについては、現状では複数のはんだが採用されており、それらを列記する。

ボード実装（推奨）Sn-3Ag-0.5Cu　　リフロー：Sn-3Ag-0.5Cu ＞ Sn-Ag ＞ Sn-Zn-Bi、
フロー：Sn-3Ag-0.5Cu ＞ Sn-Cu、
手はんだ：Sn-3Ag-0.5Cu

部品　　はんだボール（**推奨**）　：**Sn-3Ag-0.5Cu**
部品ランド処理（**推奨**）：めっき／Au、はんだプリコート／**Sn-3Ag-0.5Cu**
部品電極､端子めっき（**現状**）：
半導体部品めっき：Sn-Biめっきが多い.　Sn-Bi ＞ Sn-Cu ＞ Sn ＞ Sn-Ag ＞ Au-Pd
受動部品めっき：Snめっきが主.　Sn ＞ Sn-Cu ＞ Sn-Bi
接続部品めっき：Sn-CuめっきとSnめっきが多い.　Sn-Cu ＞ Sn ＞ Au

７．部品耐熱性評価基準

当面、フロー耐熱性評価については、温度：260Ｃ、10秒を基準とする。

リフロー耐熱性評価の温度プロファイルについては、機器側は台形プロファイル、部品側は山型プロファイルを想定する傾向にあるが、台形プロファイルへの移行を推奨する（別紙参照）。

８．設計自体を大きく変えることなく、設備やプロセスの変更によって鉛フリー化と省エネを推進する。

９．鉛フリー化の表示の業界標準化を推進する。

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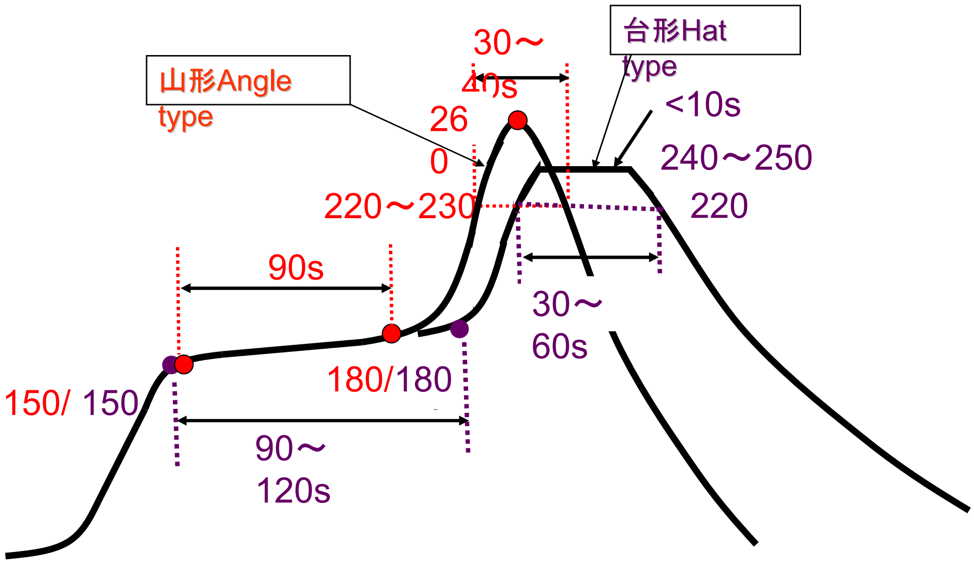
部品耐熱性評価用リフロー温度プロファイル



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Framework of the *Lead-free World Roadmap*

1) **General View of "Lead-free"**
There is a recognized need to have a definition for lead-free. There is still some debate over the exact value. However, there is a general view that European legislation and the JEITA roadmap will use a target of 0.1w percent.

2) **Milestones in Lead Elimination**
The following schedule has been set as an average of manufacturers.
Components: Commenced supplies of lead-free components/lead-free terminal components: by the end of 2001
Complete lineup of lead-free terminal components: by the end of 2003
Complete lineup of lead-free components: by the end of 2004
Equipment: Commence manufacturing of lead-free soldering assemblies: by the end of 2002
Complete lead elimination from products: by the end of 2005
Leading manufacturers will achieve these results one year ahead of this schedule, other manufacturers one year later.

3) **Lead-free Solder Alloy Selection**
The type of solder composed of Sn-Ag-Cu is recommended for board assembly.

4) **Compatibility with Existing PWBs**
Lead-free solder technology has been shown to be compatible with existing PWBs.

5) **Identification of Lead-free Material Contents**
Identification of material contents is needed for rework and/or recycling; further work is required to develop a recommended system for labeling.

JEITA

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METIプロジェクト「高密度実装における新接合技術の信頼性評価方法の標準化」(‘01～’03)　実施体制

社）電子情報技術産業協会
新接合技術標準化研究委員会

- 接合耐久性試験方法分科会
  各種接合信頼性評価項目の明確化と標準化　主査:高橋氏(東芝)
- はんだ付け性試験方法分科会
  鉛フリーはんだでの評価項目・条件の明確化と標準化　主査:中村氏(TDK)
- ウィスカ試験方法分科会
  ウィスカ発生と成長のメカニズム解析と評価項目・条件の明確化・標準化　主査:坂本氏(オムロン)
- マイグレーション試験方法分科会
  主査:戸井氏(エスペック)

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METIプロジェクト「高密度実装における新接合技術の信頼性評価方法の標準化」の成果物（1）

はんだ材料

・IEC61190－1－2：Requirements for soldering pastes for high-quality interconnects in electronics assembly

・IEC61190－1－3：Requirements for electronic grade solder alloys and fluxed and non-fluxed solid solders for electronic soldering applications

はんだ付け試験方法

・IEC60068－2－54：Solderability testing of electronic components by the wetting balance method

・IEC60068－2－58：Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)

・IEC60068－2－69：Solderability testing of electronic components for surface mounting devices (SMD) by the wetting balance method

ウィスカ試験方法

・IEC60068－2－82：Whisker test methods for electronic and electric components

2007/10/30　17

METIプロジェクト「高密度実装における新接合技術の信頼性評価方法の標準化」の成果物（2）

接合耐久性試験方法

・JEITA　ET－7409：はんだ接合耐久性試験方法一鉛フリーはんだによる表面実装部品又は挿入実装部品のはんだ接合部の接合耐久性試験方法の選定方法

・JEITA　ET－7904／101：ガルウィング形表面実装部品のはんだ接合部の引き剥がし強度試験方法

・JEITA　ET－7904／102：表面実装部品のはんだ接合部の横押しせん断強度試験方法

・JEITA　ET－7904／103：トルクせん断強度試験方法

・JEITA　ET－7904／104：限界曲げ強度試験方法

・JEITA　ET－7904／105：繰り返し曲げ強度試験方法

・JEITA　ET－7904／106：繰り返し落下衝撃強度試験方法

・JEITA　ET－7904／201：挿入実装部品のはんだ接合部の引張り強度試験方法

・JEITA　ET－7904／202：クリープ強度試験方法

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METIプロジェクト「高密度実装における新接合技術の信頼性評価方法の標準化」の成果物（3）

接合耐久性試験方法（続き）

- ・IEC62137－1－1：Environmental and endurance test methods for surface mount solder joint - Part 1-1: Pull strength test
- ・IEC62137－1－2：Environmental and endurance test methods for surface mount solder joint - Part 1-2: Shear strength test

2007/10/30 19

JEITA鉛フリーはんだ成果報告会2004

鉛フリーはんだ切替え完遂のための緊急提言

2004年6月29日（大阪），7月1日（東京）

鉛フリーはんだ実用化
ロードマップ作成委員会有志

2007/10/30 20

鉛フリーはんだ実用化ロードマップ～機器と部品の連携～

３．鉛フリー化のマイルストーン：平均的メーカーに対して、下記のスケジュールを設定

部品：鉛フリー対応部品／鉛フリー端子部品の供給開始：2001年末、
鉛フリー端子部品の品揃え完了：2003年末。
鉛フリー部品の品揃え完了：2004年末。
機器：鉛フリーはんだの導入開始：002～2003年2
鉛フリー化完了：2006年末（EU-RoHS-2007を想定）

部品：鉛フリー対応部品／鉛フリー端子部品の供給開始：2001年末
鉛フリー端子部品の品揃え完了：2003年末。
＊　ウイスカ（コネクタ）発生
鉛フリー部品の品揃え完了：2004年末。
機器：鉛フリーはんだの導入開始：002～　2003年2
＊　低温はんだ
＊　はんだ槽浸食
＊　接合部0.1%Pb含有量etc.
鉛フリー化完了：2006年末（EU-RoHS-2007を想定）

緊急対応が不可欠

０５年５月日本全体として着地できるのか？！

2007/10/30　21

緊　急　提　言　！！

ねらい

◆各重点課題の応急対策の明確化 ➡ 2004年12月必達

重点課題と応急策取り組み

◆はんだ槽浸食
⇒　鋳物はんだ槽、静圧方式はんだ槽　etc.
◆ウイスカ応急対策
⇒　Auﾒｯｷ代替SnBiﾒｯｷ　etc.
◆低温はんだ
⇒　190℃狙い　Zn系、Bi系、In系etc
◆はんだ接合部Pb含有量0.1%
⇒　高精度Pb検出器，部品ﾒｯｷオール鉛フリー

ｽｹｼﾞｭｰﾙ

◆10月緊急シンポジウム、2004年12月応急対策報告会開

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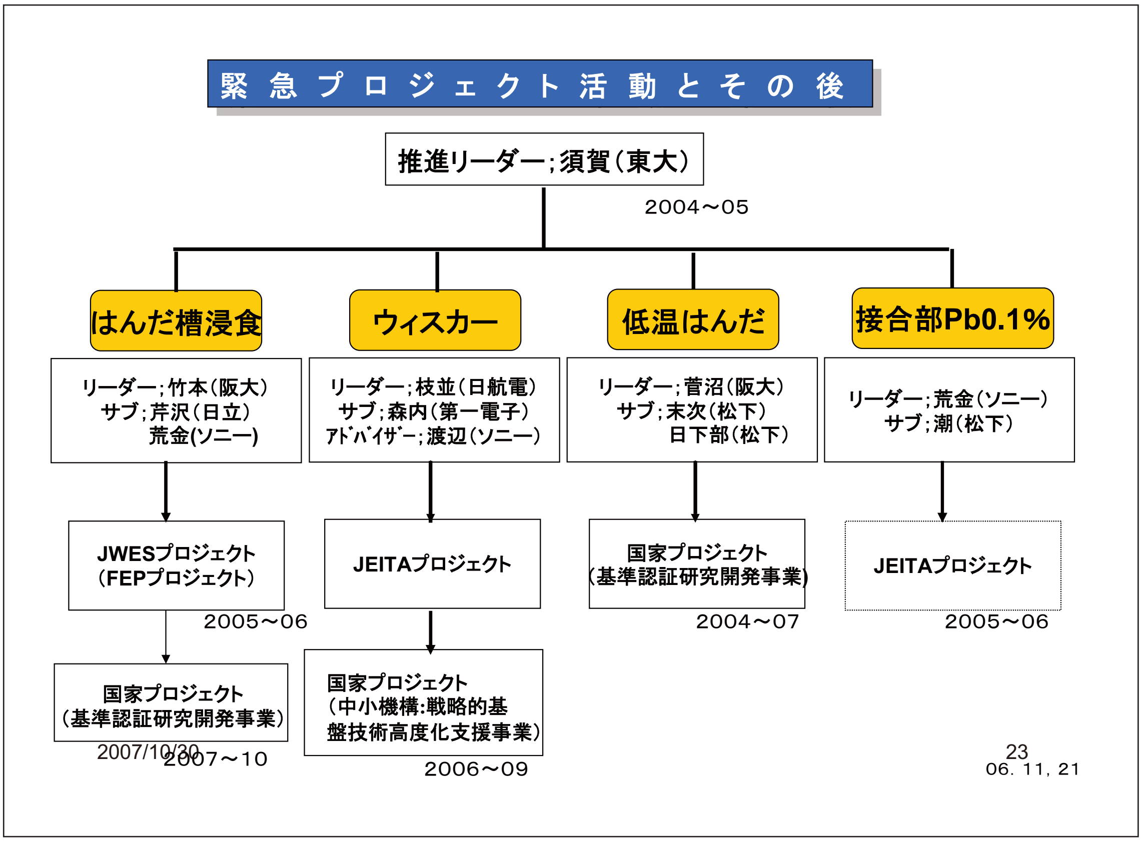
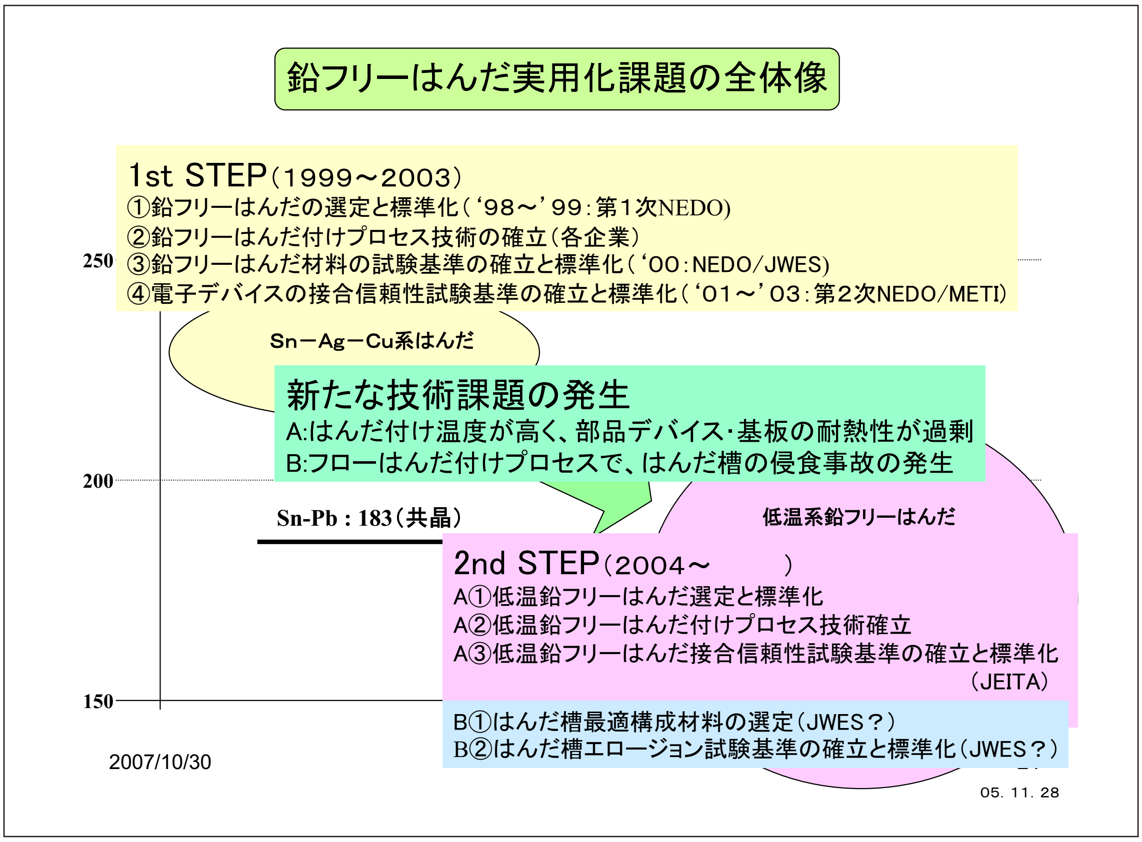

緊 急 プ ロ ジ ェ ク ト 活 動 と そ の 後
推進リーダー;須賀(東大)
2004～05
はんだ槽浸食
ウィスカー
低温はんだ
接合部Pb0.1%
リーダー;竹本(阪大)
サブ;芹沢(日立)
荒金(ソニー)
リーダー;枝並(日航電)
サブ;森内(第一電子)
ｱﾄﾞﾊﾞｲｻﾞｰ;渡辺(ソニー)
リーダー;菅沼(阪大)
サブ;末次(松下)
日下部(松下)
リーダー;荒金(ソニー)
サブ;潮(松下)
JWESプロジェクト
(FEPプロジェクト)
2005～06
JEITAプロジェクト
国家プロジェクト
(基準認証研究開発事業)
2004～07
JEITAプロジェクト
2005～06
国家プロジェクト
(基準認証研究開発事業)
2007/10/30
2007～10
国家プロジェクト
(中小機構:戦略的基盤技術高度化支援事業)
2006～09
23
06. 11, 21


鉛フリーはんだ実用化課題の全体像
1st STEP(1999～2003)
①鉛フリーはんだの選定と標準化(‘98～’99:第1次NEDO)
②鉛フリーはんだ付けプロセス技術の確立(各企業)
③鉛フリーはんだ材料の試験基準の確立と標準化(‘00:NEDO/JWES)
④電子デバイスの接合信頼性試験基準の確立と標準化(‘01～’03:第2次NEDO/METI)
250
Sn－Ag－Cu系はんだ
新たな技術課題の発生
A:はんだ付け温度が高く、部品デバイス･基板の耐熱性が過剰
B:フローはんだ付けプロセスで、はんだ槽の侵食事故の発生
200
Sn-Pb : 183(共晶)
低温系鉛フリーはんだ
2nd STEP(2004～　　　)
A①低温鉛フリーはんだ選定と標準化
A②低温鉛フリーはんだ付けプロセス技術確立
A③低温鉛フリーはんだ接合信頼性試験基準の確立と標準化
(JEITA)
150
B①はんだ槽最適構成材料の選定(JWES？)
B②はんだ槽エロージョン試験基準の確立と標準化(JWES？)
2007/10/30
05. 11. 28

経産省プロジェクト
低温鉛フリーはんだ実装のための基盤技術確立と標準化

期　間：平成16年10月～19年3月 ＋ 1年

組　織：

社）電子情報産業技術協会
低温鉛フリーはんだ実装
基盤技術標準化研究委員会

財）電子部品信頼性センター
環　境　試　験　所

- 接合信頼性試験方法分科会
  - 各種信頼性評価項目の明確化と標準化
- 低温鉛フリーはんだ付け
  プロセス分科会
  - 各種プロセス条件の明確化と標準化
- 力学的特性評価方法分科会
  - 微細接続及びボイド形成影響評価と標準化

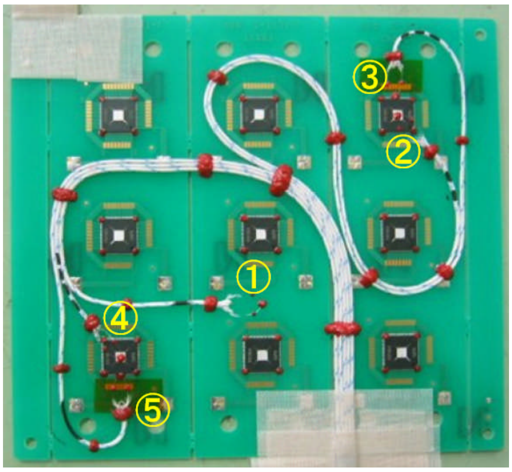
目指す標準

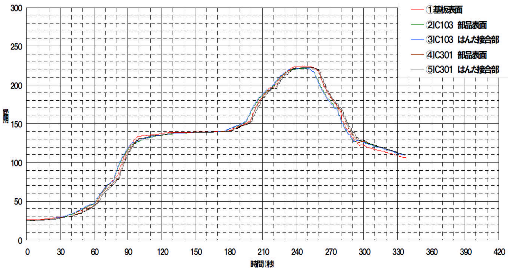
① 低温鉛フリーはんだ実装の接合信頼性試験方法
② 低温鉛フリーはんだに対応した電子デバイスのはんだ付け性試験方法
③ 低温鉛フリーはんだ接合部の信頼性に対するボイド許容基準
④ 低温鉛フリーはんだ微細接合部の力学的信頼性評価方法

2007/1　　5

K.Suganuma, ISIR, Osaka University

2007/10/30　パナソニックファクトリーソリューションでの実装風景　26





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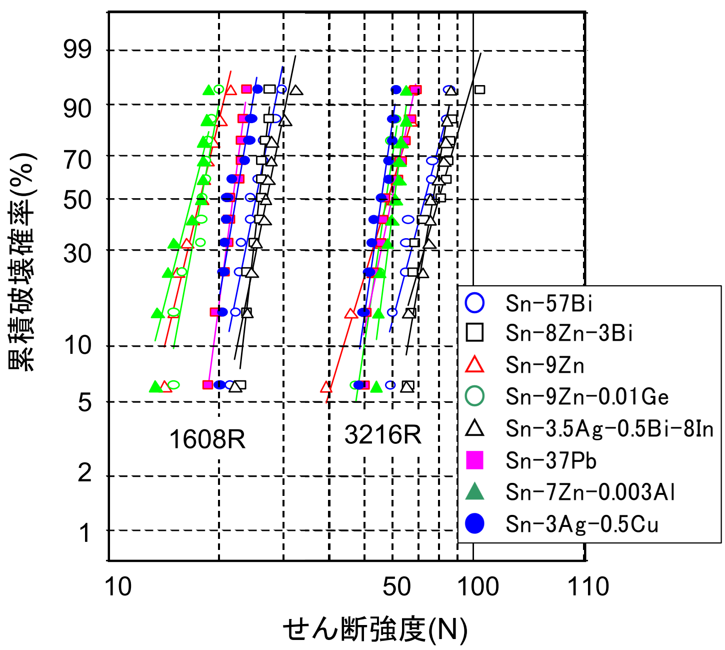
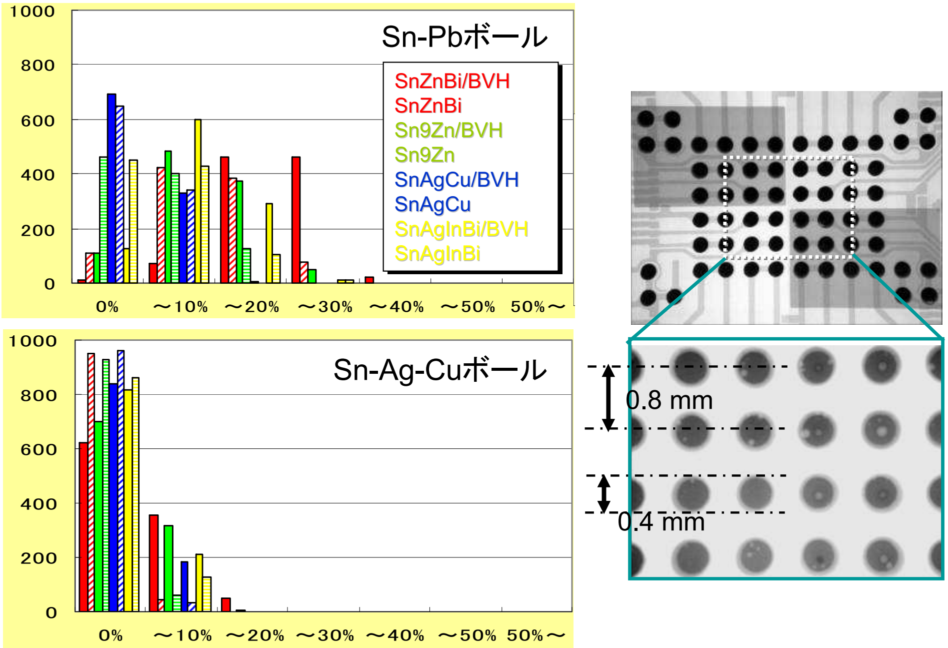
QFN実装基板のレイアウトと温度プロファイルの例



2007/10/30 28

1608Rと3216Rのせん断強度のワイブルプロット
（Cu上、フラックス有り、85℃/85%RH-1000時間後）



2007/10/30 29

BGA実装におけるボイド発生状況に及ぼすSn-Ag-CuボールとSn-Pbボールの影響。横軸はボイド面積率を示す。

METIプロジェクト「低温鉛フリーはんだ実装のための基盤技術確立と標準化」の成果物

- JEITA ET－XXXX 低温鉛フリーはんだによるはんだ接合部の接合耐久性試験方法の選定方法（仮称）
- IEC60068－2－54：Solderability testing of electronic components by the wetting balance methodへの低温鉛フリーはんだに関する事項の挿入（原案作成中）
- IEC60068－2－58：Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)への低温鉛フリーはんだに関する事項の挿入（原案作成中）
- 91／707／CD：IEC 61193-5 Evaluation criteria for voids in soldered joints of BGA and LGA
- 91／695／CD：IEC 62137-1-5, Ed. 1: Surface mounting technology - Environmental and endurance test methods for surface mount solder joints - Part 5: Mechanical shear fatigue test

2007/10/30 30

中小機構・戦略的基盤技術高度化支援事業

『電子実装の信頼性向上のための ウィスカ防止技術の開発』

大阪大学 菅沼克昭

目 標

- ✓ Snウィスカメカニズム解明で根本対策
- ✓ 根本原理で世界を説得
- ✓ 日本発のSnウィスカ抑制技術を世界の標準へ
- ✓ 抑制技術と評価技術をセットで提供
- ✓ 信頼性評価技術と基準を作り、安心設計
 → 世界のデファクト化

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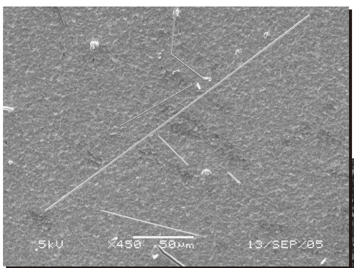
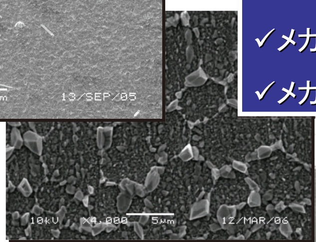
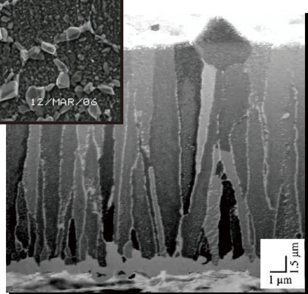
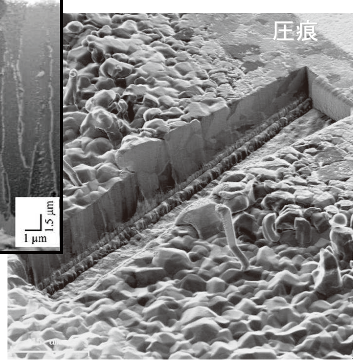
Snウィスカの発生メカニズムと抑制は？

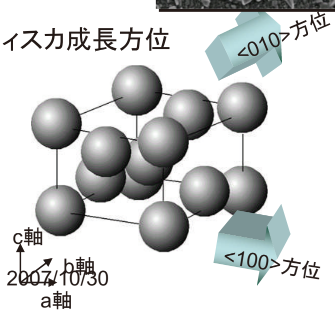




- ✓5種類の環境条件を切り分けねばならない
  室温、温度サイクル、腐食・酸化、
  外圧、エレクトロマイグレーション
- ✓メカニズムはかなり分かってきた
- ✓メカニズムから抑制策も可能になりつつある







2007/10/30

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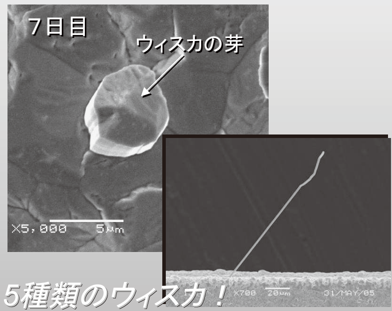
ウィスカの問題は世界の長年の課題

- 従来技術は1週間でウィスカの芽
  → 数ヶ月後には100μmに！
- ウィスカで鉛フリー化にブレーキ！
- メカニズムに不明な点多い
- Snめっきは室温で変化する生もの
  →解析法も分からない
- 日本はSn合金推奨 ⇔ 欧米は純Sn推奨
  →アジアの選択は欧米へ！

従来技術の限界



メカニズム不明で対策も不安

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K. Suganuma, ISIR, Osaka University

〈実施体制〉

中小企業基盤整備機構

↓ 委託

事業管理法人：社団法人電子情報技術産業協会

↓ 再委託

- **大阪大学**
  •めっき表面構造の解析技術を確立し、ウィスカ発生への影響を調査
- **石原薬品**
  •半導体リードフレームから発生するウィスカの発生要因を解明し、ウィスカ抑制技術の確立
- **ユケン工業**
  •FPC及びFFCから発生するウィスカの発生要因を解明し、ウィスカ抑制技術の確立
- **ニホンゲンマ**
  •鉛フリーはんだから発生するウィスカの発生要因を解明し、ウィスカ抑制技術の確立
- **荏原ユージライト**
  •電解コンデンサに発生するウィスカの溶接条件及び結晶方位の関係を明らかにして、抑制策を開発
- **ニシハラ理工**
  •めっき条件の最適化と量産化レベルでのウィスカ抑制技術確立のためのめっき量産試作ライン

技術支援

東北大学、横浜国立大学、東海大学、九州大学、熊本大学
基礎メカニズムの解明

技術支援

電子機器、電子部品メーカー
信頼性評価基準と評価技術確立

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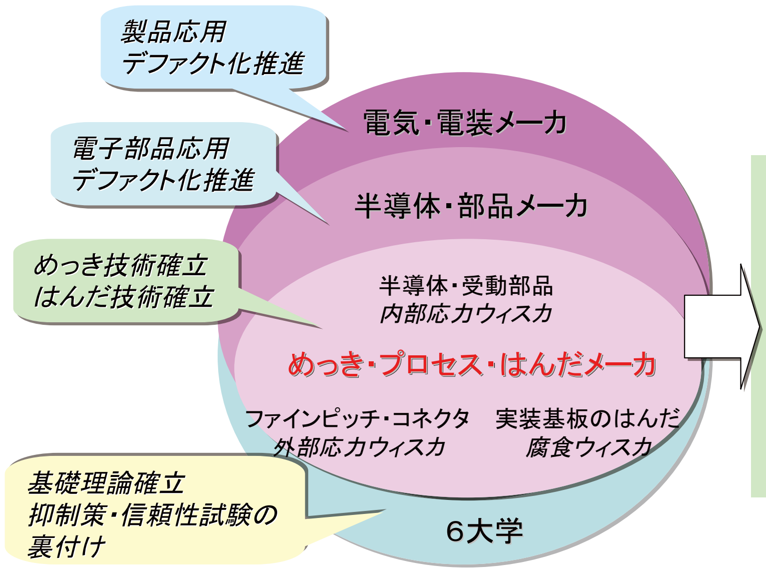
K. Suganuma, ISIR, Osaka University

『ウィスカ防止技術開発』研究開発



世界の標準を確立

ウィスカ基礎メカニズム

ウィスカ抑制方法

新めっき・はんだ・部品・プロセスのデファクト化

信頼性評価技術

強　み

認定川上企業から中間電子部品企業、最川下ユーザ企業、大学を組織に幅広く含み、産官学の世界に負けない共同体を形成するとともに、完結したサプライチェーンをも形成している。

『ウィスカ防止技術開発』研究開発の流れ

ウイスカ発生のメカニズムと抑制方法(主として大学委託)

1. ウイスカ発生のメカニズム解明
2. ウイスカ加速試験方法の標準化（温度、湿度、その他評価時の条件）
3. 抑制メカニズム提案

ウイスカ抑制するめっき条件の確立（各薬品メーカー）

1. めっき液・はんだ組成の検討
2. めっき条件・実装条件の最適化（膜厚、電流密度、液かくはん条件、下地処理、合金濃度、フラックス等）
3. めっき前後処理

量産化レベルでのウイスカ抑制管理技術（プロセス・部品メーカー）

1. 試作量産レベルへの落とし込み
   実機サイズの試料で評価を行い、量産化に向けての検討
2. 各めっき液メーカーは標準化しためっき装置で行ない、共通条件での評価を行う

信頼性評価基準と技術・デファクト形成（セット中心・全社）

1. アプリに依存したウィスカ評価と成長許容規準確立
2. 各種ウィスカによる機器寿命評価式と試験方法の確定

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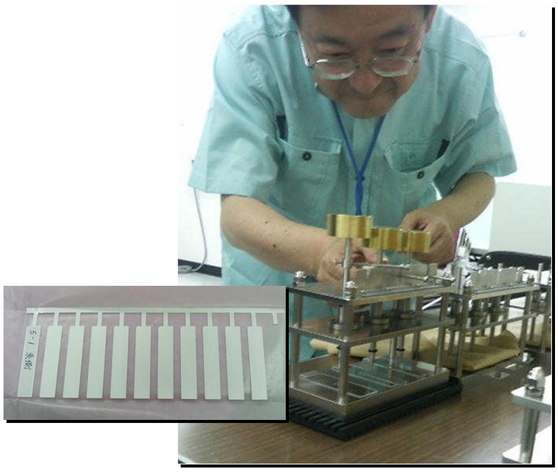
K. Suganuma, ISIR, Osaka University

プロジェクト実験・開発作業の様子



2　37

METIプロジェクト「鉛フリーはんだを用いたフローはんだ付け機器の損傷抑制技術の評価試験方法に関する標準化」（‘07～’09） 実施体制

- 社）電子情報産業技術協会 フロー槽損傷抑制技術 標準化研究委員会
  - 材料・メカニズム分科会
  - 表面処理分科会
  - 寿命評価分科会
- 財）日本電子部品信頼性センター 環　境　試　験　所

2007/10/30　38

06/07/11,14 JEITA鉛フリー化成果報告会

JEITA第2世代フロー用鉛フリーはんだ標準化検討

JEITA 第2世代フローはんだ合金
標準化PG

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参加メンバ

your partner for soldering solution
NIHON SUPERIOR
SMIC
Senju Metal Industry Co., Ltd.
Panasonic
SHARP
kester
CONNECTING INNOVATION™
TOPY
NIPPON FILLER METALS LTD.
FUJITSU
TAMURA
株式会社ニホンゲンマ
NIHON GENMA MFG. CO.,LTD.
OKI
HITACHI
Inspire the Next
muRata
Innovator in Electronics
NIHON HANDA
TOSHIBA
協和電線株式会社（古河電工グループ）
SONY
Victor・JVC
Cookson Electronics

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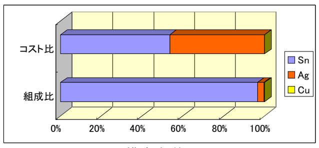
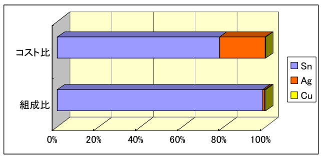
第2世代フロー合金への期待

既存はんだの問題点 （設立準備会での意見より）
- 構成主材料の高騰
- 錫ー銅系は、はんだ上がりが悪いためスルーホールには使えない
- 銅箔喰われ（細り）の問題



Sn3Ag-0.5Cuのコスト構造（概算）

“コストが最大のキーファクターである”



Sn1Ag-0.5Cuのコスト構造（概算）

第2世代フロー用はんだの必要性

「Sn−3.0Ag−0.5Cuを要求されるプロダクツ以外の用途に
使用できる低コストな材料」

失われる特性が定量化出来れば、ユーザで可否判断できる

e.g.

·表面光沢	・・・・・	つや消し使用も可能
·スルーホール上がり	・・・・・	上面の小さな窪み（えくぼ）を可とする
·銅喰われ	・・・・・	通常作業で問題なきこと
·ドロス	・・・・・	通常作業でSn−3.0Ag−0.5Cuと同等で可
·オペレーション温度	・・・・・	255℃がMax（部品の耐熱限界）
·コストダウン	・・・・・	Sn−3.0Ag−0.5Cuの20％以上（銀1％で約10％のコスト）

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実験の流れ

はんだ合金

Sn−3Ag−0.5CuをRef.として

ラボ試験 / 実機試験

試験	品種数
試験方法の確認 （予備実験）	
1次試験	27品種
1．5次試験（追加）	12品種
絞込み ↓ 2次試験（実装評価）	3品種
推奨組成	2品種

はんだの提案

Ⅰ．はんだメーカより多くの提案組成を受ける
　特許 ： 有償、無償にかかわらず公平且つ妥当な対価で公開を前提とする。

Ⅱ．静特性試験にて候補組成を絞り込む
（全ての組成案を実機で評価するのは非現実的）

実験

1．静特性（ラボ実験）と動特性（実機実験）に分ける

2．静特性試験
　Ⅰ．フローに必要な特性を代替特性で評価
　Ⅱ．誰が何処で実験しても同じ結果が得られる

3．動特性試験
　Ⅰ．実際に商品に使用している基板を、生産ラインの実機を用いた時の動特性と作業性の評価

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結論

- SAC0307 は、低コストと濡れのバランスに優れる。
  濡れは明らかに悪化するため、作業温度下限を250℃、十分な1次浸漬時間（1．5sec以上）を確保し、かつ部品損傷条件に対してマージンの確保できる（±2.5℃以内の温度制御）装置の使用が前提になる。また、若干の耐ヒートショック性の悪化があるため、使用基板別に試験検証の上、導入すべきである。製造歩留まりは、適切なフラックスの選定で十分なレベルを期待できるが、100％のTH上がりは実現厳しい。
- SAC107 は、濡れと耐ヒートショック性のバランスで有利。上記SAC0307で述べた装置条件では、SAC305に近い特性が得られるが、大熱容量部で濡れに差が見られる。TH上がり100％が製造要求の場合の低Ag化の下限組成。逆にリード部品のブリッジ性能はSAC0307より劣るため、基板別波形設定を正確に行う必要がある。

- 以上、2組成
  1．SAC107
  2．SAC0307
  をフローはんだ用　次期標準組成として推奨する。

- 目的を持った微量添加元素については
  - P：ドロス発生の低減
  - Ni：銅食われの低減

  をオプションとして認める。但し、副作用があるため作業温度に応じた上限値管理が必須である。

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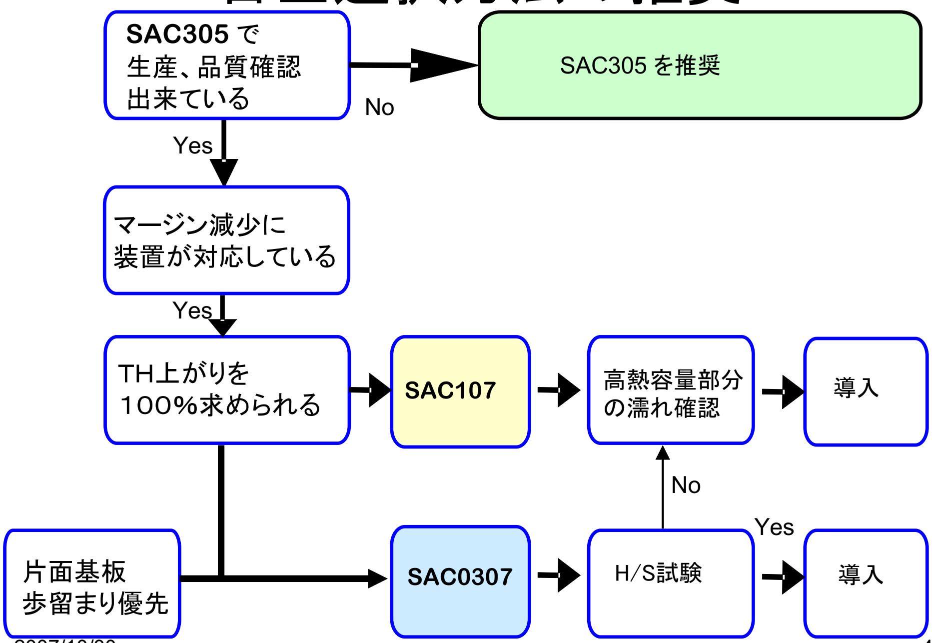
合金選択方法の推奨



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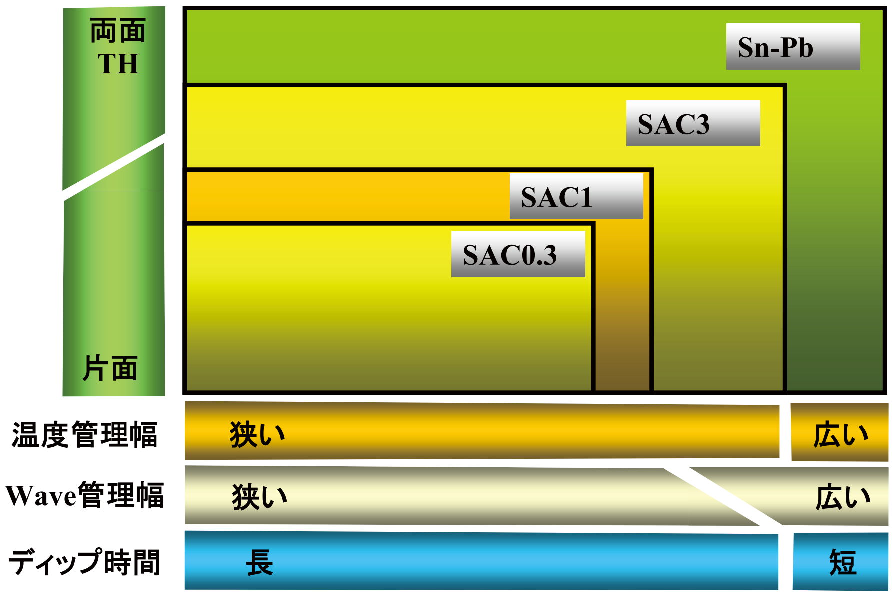
実装プロセスウィンドウの変化（イメージ）



フロー装置条件設定、作業性

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ご清聴ありがとうございました。

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Promoting Lead-Free in Japan

October 30, 2007
Katsumi Yamamoto
Vice-chairman of Jisso Technology
Standardization Committee
（Techno Office Yamamoto ）

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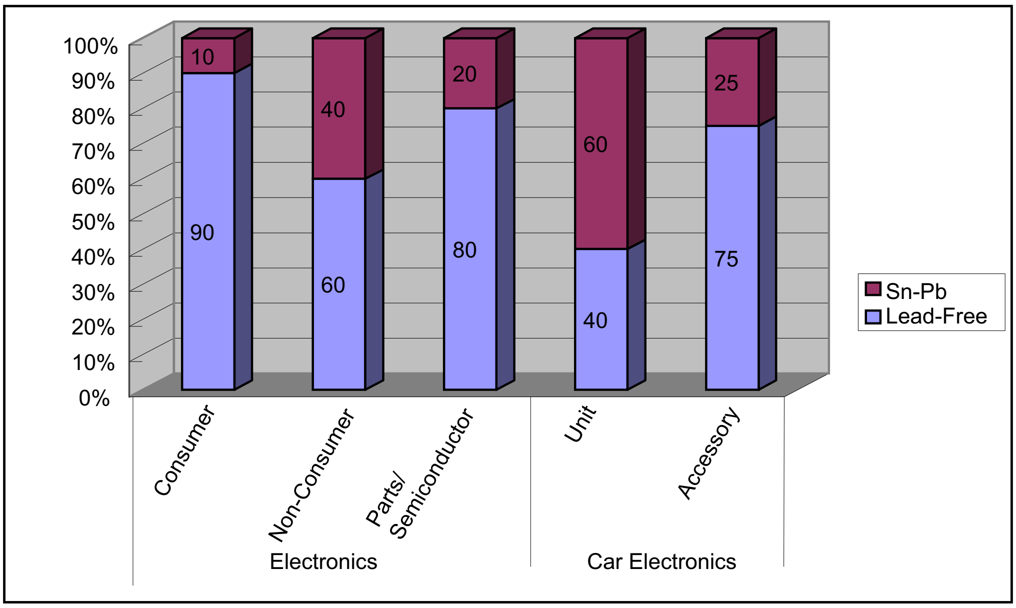
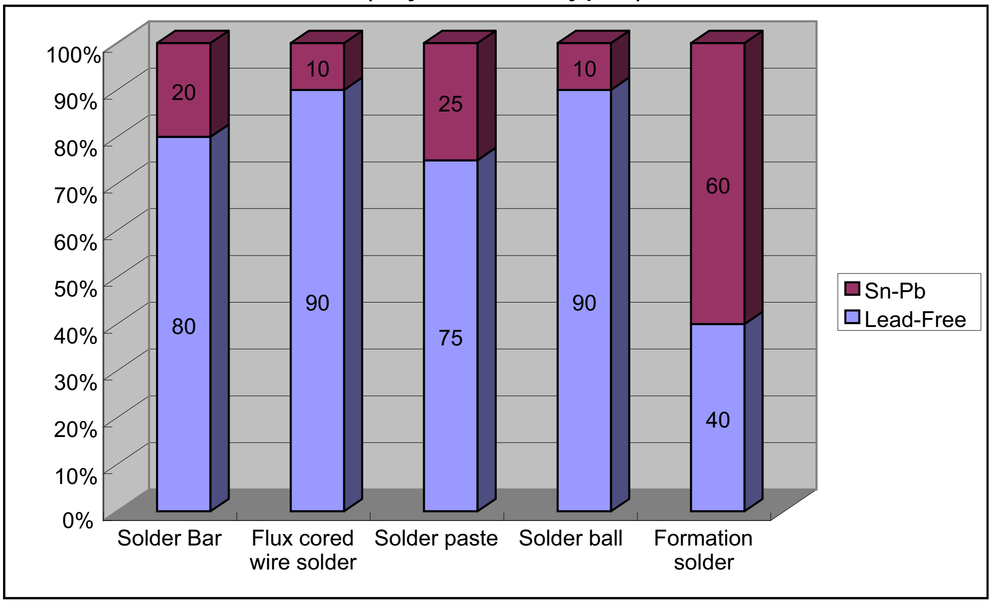
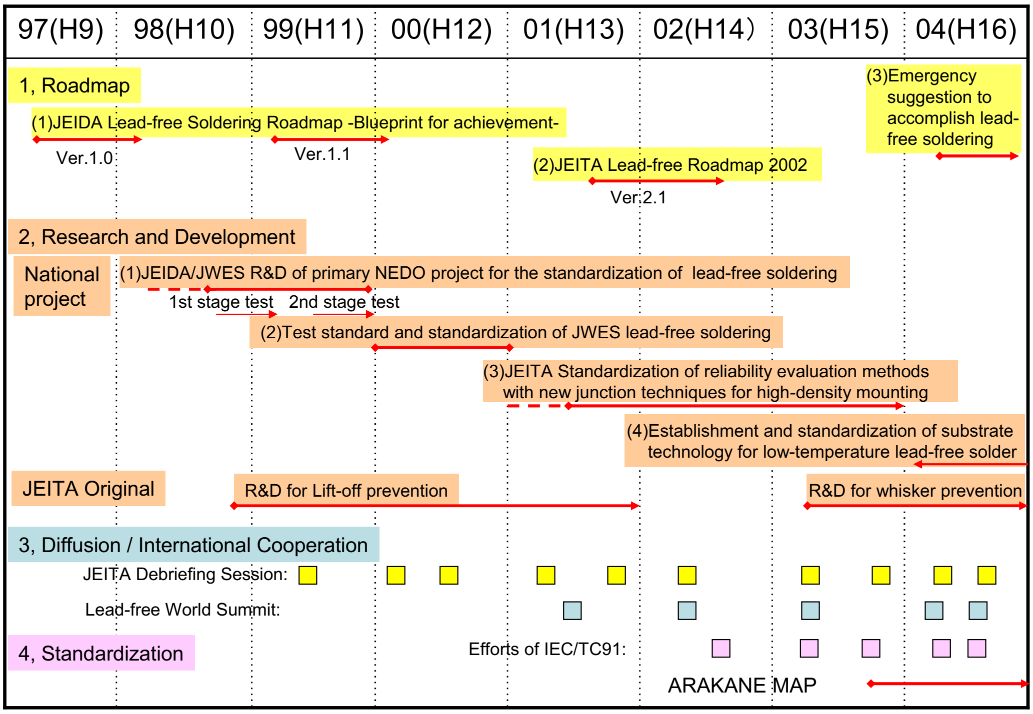
Lead-Free Solder Adoption Rate in Japan
(Electronics vs. Car Electronics)



Lead-Free Solder Adoption Rate in Japan (By Solder Type)





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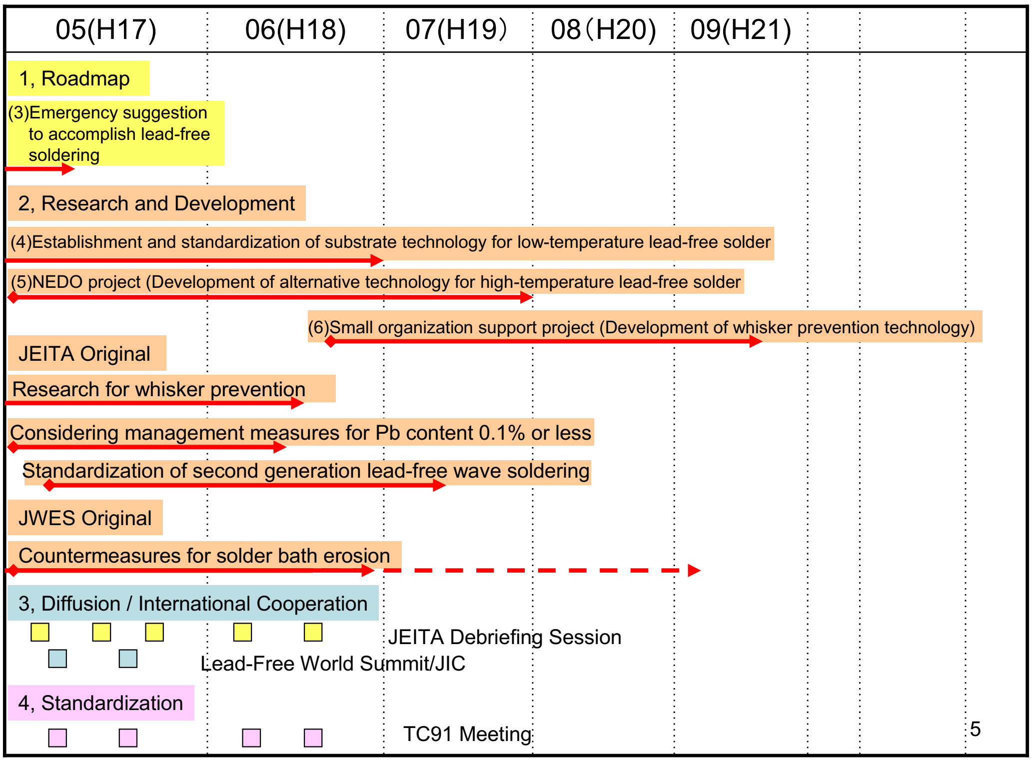
Development of Lead-Free Industry

Nov. 28, 2005 Yamamoto



Nov. 21, 2006

Challenges and Efforts Toward Commercialization of Lead-free Solder

Roadmap 2000 for Commercialization of Lead-free Solder

Ver. 1.3

August 2000

R&D Committee for Lead-Free Soldering

JEIDA

Japan Electronics and Information Technology Industries Association

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Chapter 3 List of lead-free solder alloys selection

The following is a list of lead-free solder alloys which are considered to be possible candidates for the commercial use, including wave soldering, reflow soldering, and manual soldering. When using them, your attention should be paid to the points noted in the table. It is also necessary to establish the universal database in order to fully grasp the performance and reliability of those alloys.

Table 3.1 List of Lead-free Solder Alloys

Process		Alloys used for practical application	Composition preferred from point of view of cost and performance	Note
Wave		Sn-3.5Ag		Sn-Pb plating on components might cause fillet lifting and damage to boards
		Sn-(2-4)Ag-(0.5-1)Cu	Sn-3Ag-0.5Cu	
		Sn-0.7Cu with a very small amount of other elements(Ag, Au, Ni, Ge, In, etc.) added		
Reflow	Medium and High Temp.	Sn-3.5Ag		Needs temperature control for reflow at higher temp.
		Sn-(2-4)Ag-(0.5-1)Cu	Sn-3Ag-0.5Cu	
		Sn-(2-4)Ag-(1-6)Bi, including the ones with 1-2% of In		Incompatibility with Sn-Pb plated components when it contains some % of Bi.
		Sn-(8-9)Zn-(0-3)Bi	Sn-8Zn-3Bi	Handle carefully Sn-Zn in corrosive environment. Ni/Au finishes preferred for Cu electrode at high temp.
	Low Temp.	Sn-(57-58)Bi	Sn-57Bi-1Ag	Incompatibility with Sn-Pb plated components
Manual/Robot (Thread Solder)		Sn-3.5Ag		Incompatibility with different solder alloys in reworking.
		Sn-(2-4)Ag-(0.5-1)Cu	Sn-3Ag-0.5Cu	
		Sn-0.7Cu with a very small amount of other elements(Ag, Au, Ni, Ge, In, etc.) added		

(Unit wt%)

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Chapter 4 Roadmap toward the introduction of the lead-free solders

Here we made a roadmap toward the introduction of the lead-free soldering based on the discussion and research we have made. It should be noted that this is the roadmap not for completing the lead-free soldering, but for introducing it. However, it is desirable to vigorously take part in the activity, considering the fact that the vast amount of annual electronics wastes is about to surpass the capacity of the waste treatment plant in our country. As is observed currently, reflow soldering is introduced earlier than the wave soldering. This is because the problem of the fillet lifting in wave soldering is difficult to be resolved until all components are plated with lead-free alloys, and because the heat-resistance of components and boards must be improved. Thus, it is awaited to create the environment which can provide incentives for the components and board suppliers to work on this issue.

First adoption of lead-free solders in mass-produced goods..............	1999
Adoption of lead-free components..	2000
Adoption of lead-free solders in wave soldering...............................	2000
Expansion of use of lead-free components...	2001
Expansion of use of lead-free solders in new products......................	2001
General use of lead-free solders in new products..	2002
Full use of lead-free solders in all new products.	2003
Lead-containing solders used only exceptionally................................	2005

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NEDO Lead-free Soldering Project ('98~'99)

Conclusion of『R&D for Standardization of Lead-free Solders』

- **In combination of existing Sn-Pb plated parts and lead-free solder candidates, the interconnect reliability decreases as the Bi content of solder increases.**
- **In combination of lead-free plated parts and lead-free solder candidates or existing Sn-Pb solder, the test results varies, but there are no significant problems.**
- **Regarding solderability, good wettability is basically maintained. As for Sn plated solder, the temperature to maintain stable wettability tends to be high.**

lead-free solder candidates

Sn-3.5Ag-0.7Cu
Sn-2Ag-3Bi-0.75Cu
Sn-2Ag-4Bi-0.5Cu-0.1Ge
Sn-3Ag-5Bi-0.7Cu
Sn-3.5Ag-6Bi
Sn-0.7Cu
Sn-37Pb (Reference)

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Lead-free Roadmap 2002

Roadmap 2002 for Commercialization of Lead-free Solder

Ver. 2.1

September 2002

Lead-Free Soldering Roadmap Committee

Technical Standardization Committee on Electronics Assembly Technology
JEITA
Japan Electronics and Information Technology Industries Association

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1. Definition of Lead-free

Definition of lead-free: In the following phases, the amount of contained Pb in the prescribed parts planned for lead-free adoption should be less than 0.1w percent. The value must be given if it exceeds that amount. If there is any exemption, the definition refers to the rest parts of the product, with indication of the name of the item of the exemption and the amount of contained Pb.

Components

Phase 1 — Components withstand heat resistance: Heat resistance against soldering in assembly with lead-free solder.

Phase 1A — Components with lead-free solder: Module components etc. Correspond to Phase1 in Equipment.

Phase 2 — Lead-free terminal components: No lead contained plating and electrodes of terminal parts of components assembled to PWB etc. The components may contain leaded composing components and materials.

Phase 3 — Lead-free components: No lead contained in all the internal bonding and/or composing components and materials.

Equipment

Common definition in the equipment for lead-free: No leaded solder is used at the stage of board assembly in board surface finishing, solder paste and solder bath.

Phase 1 — Equipment with lead-free solder A: Application of current components or components withstand heat resistant, Phase1 (Composing components and materials may contain lead, while the assembly solder is lead-free)

Phase 2 — Equipment with lead-free solder B: Application of lead-free terminal components, Phase2, or lead-free components, Phase3 (Even if the assembled components are lead-free, the other components and materials may contain lead)

Phase 3 — Lead-free equipment: Application of lead-free components, Phase3, only and non leaded composing components and materials in addition to assembled components and bonding materials.

Phase 0 — Lead-free component equipment: Application of lead-free terminal components, Phase2, or lead-free components, Phase3, with lead-bearing solder in bonding materials (Excluded from the category of lead-free equipment)

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2. The lead-free regulation in the EU will be accepted with reluctance in Japan, if it is crucial for the environment. In that case, the same kind of regulation should be required also in Japan.

A global agreement on the definition of lead-free and on the standard for judgment is needed as early as possible.

3. Timeline for lead-free: Set up the schedule for the average manufacturers as follows.

Components: Start supplying components withstand heat resistance / lead-free terminal components: 2001
Complete supplying of lead-free terminal components: 2003
Complete supplying of lead-free components: 2004

Equipment: Start introducing lead-free solder: 2002-2003
Totally adopt lead-free solder into new products: 2003
Complete lead-free adoption: 2005

The "leading makers" are 1 year ahead of this schedule, and the "followers" are 2 years behind.

There is a need to establish a worldwide milestone and a roadmap.

4. Combined packaging of lead solder for PWB and lead-free terminal components (Phase 0 in equipment)

In the stage of shifting to lead-free, packaging of lead-free terminal components with lead solder (=Phase 0) should be allowed.

Component and equipment makers should work together on shortening the transition period, as the components makers have to prepare both lead-free terminal components and lead components.

5. Promote lead-free adoption corresponding to moving production plants overseas, components procurement overseas, and technology overseas.

Equipment: Promote technology transfer overseas. Give technology to overseas cooperative plants.
Require that overseas plants cope with lead-free adoption 1 year behind at latest.
Require that they cope with purchased and procured products immediately.

Components: Require that overseas plants cope with lead-free adoption 1 year behind at latest.
There is a need of giving supports to the followers.

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6. **Standardization of lead-free solder: The following types of solder are recommended. Currently, more than one type are adopted to component electrodes and terminal plating as follows.**

Board assembly (Recommended) Sn-3Ag-0.5Cu Reflow: Sn-3Ag-0.5Cu > Sn-Ag > Sn-Zn-Bi
Wave: Sn-3Ag-0.5Cu > Sn-Cu
Hand: Sn-3Ag-0.5Cu

Components Solder balls **(Recommended):** Sn-3Ag-0.5Cu
Land finish **(Recommenced):** Plating/Au, Solder precoat/Sn-3Ag-0.5Cu
Component electrodes and terminal plating **(Current situation):**
Semiconductor components: Sn-Bi plating is majority; Sn-Bi>Sn-Cu>Sn>Sn-Ag>Au-Pd
Passive components: Sn plating is the main; Sn > Sn-Cu > Sn-Bi
Terminal finishes: Sn-Cu plating and Sn plating are the majorities; Sn-Cu > Sn > Au

7. **Assessment standard for heat resistance of components**
For the time being, the heat resistance standard for wave soldering is 260°C, 10 seconds.

As for the temperature profile for heat resistance assessment in reflow, the equipment makers are likely to assume the 'Hat type' and the component makers are likely to assume the 'Angle type'. The 'Hat type' is a recommendation. (See Exhibit.)

8. **Promote lead-free adoption and energy saving by improving facilities and processes without large changes in design.**

9. **Promote industrial standardization of lead-free labeling.**

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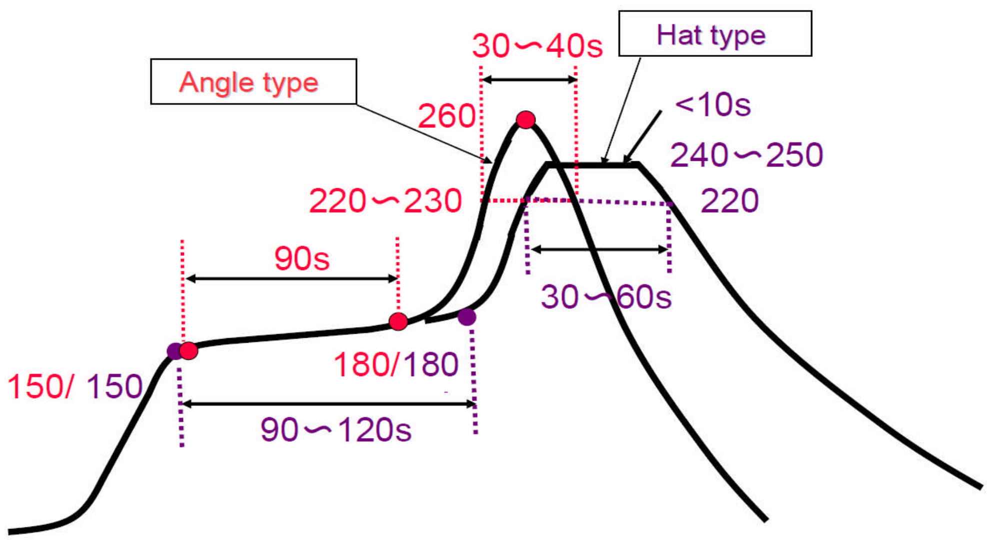
Temperature Profile for Heat Resistance Assessment in Reflow



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Framework of the *Lead-free World Roadmap*

1) General View of "Lead-free"
There is a recognized need to have a definition for lead-free. There is still some debate over the exact value. However, there is a general view that European legislation and the JEITA roadmap will use a target of 0.1w percent.

2) Milestones in Lead Elimination
The following schedule has been set as an average of manufacturers.

Components: Commenced supplies of lead-free components/lead-free terminal components: by the end of 2001
Complete lineup of lead-free terminal components: by the end of 2003
Complete lineup of lead-free components: by the end of 2004

Equipment: Commence manufacturing of lead-free soldering assemblies: by the end of 2002
Complete lead elimination from products: by the end of 2005

Leading manufacturers will achieve these results one year ahead of this schedule, other manufacturers one year later.

3) Lead-free Solder Alloy Selection
The type of solder composed of Sn-Ag-Cu is recommended for board assembly.

4) Compatibility with Existing PWBs
Lead-free solder technology has been shown to be compatible with existing PWBs.

5) Identification of Lead-free Material Contents
Identification of material contents is needed for rework and/or recycling; further work is required to develop a recommended system for labeling.

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Implementation System of METI Project: 「Standardization of Reliability Evaluation Methods with New Junction Techniques for High-Density Mounting」('01~'03)

Japan Electronics and Information Technology Industry Association
New Joint Technology Standardization Research Committee

- Joint Durability Test Method Subcommittee
  Clarification and standardization of joint reliability test items.
  Reader: Takahashi (TOSHIBA Corp.)
- Solderability Test Method Subcommittee
  Clarification and standardization of test items and conditions with lead-free solder.
  Reader: Nakamura (TDK Corp.)
- Whisker Test Method Subcommittee
  Mechanism analysis of whisker formation and growth, clarification and standardization of test items and conditions
  Reader: Sakamoto (OMRON Corp.)
- Electro-Migration Test Method Subcommittee
  Reader: Toi (ESPEC Corp.)

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Deliverables of METI Project:「Standardization of Reliability Evaluation Methods with New Junction Techniques for High-Density Mounting」(1)

Solder Material

- IEC61190-1-2: Requirements for soldering pastes for high-quality interconnects in electronics assembly
- IEC61190-1-3: Requirements for electronic grade solder alloys and fluxed and non-fluxed solid solders for electronic soldering applications

Solderbility Test Method

- IEC60068-2-54: Solderability testing of electronic components by the wetting balance method
- IEC60068-2-58: Test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD)
- IEC60068-2-69: Solderability testing of electronic components for surface mounting devices (SMD) by the wetting balance method

Whisker Test Method

- IEC60068-2-82: Whisker test methods for electronic and electric components

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Deliverables of METI Project:「Standardization of Reliability Evaluation Methods with New Junction Techniques for High-Density Mounting」(2)

Joint Durability Test Method

- JEITA ET-7409: Environmental and endurance test methods for solder joint of surface mount device or lead terminal type device Part0: Selection of the test methods　Solder joint durability test method
- JEITA ET-7409/101: Environmental and endurance test methods for solder joint of surface mount device Part101: Pull strength test
- JEITA ET-7409/102：Environmental and endurance test methods for solder joint of surface mount device Part102: Shear strength test
- JEITA ET-7409/103：Torque shear strength test
- JEITA ET-7409/104：Monotonic bending strength test
- JEITA ET-7409/105：Cyclic bending strength test
- JEITA ET-7409/106：Cyclic drop test
- JEITA ET-7409/201：Environmental and endurance test methods for solder joint of lead terminal type device Part201: Pull strength test
- JEITA ET-7409/202：Creep strength test

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Deliverables of METI Project:「Standardization of Reliability Evaluation Methods with New Junction Techniques for High-Density Mounting」(3)

Joint Durability Test Method (Continued)

・IEC62137-1-1: Environmental and endurance test methods for surface mount solder joint - Part 1-1: Pull strength test

・IEC62137-1-2: Environmental and endurance test methods for surface mount solder joint - Part 1-2: Shear strength test

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JEITA Lead-free Accomplishment Report 2004

Emergency Project to Accomplish Lead-free Soldering

Jun. 29, 2004 (Osaka), Jul. 1, 2004 (Tokyo)

Lead-free Soldering Roadmap Committee Project Members

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1. Lead-free Soldering Roadmap ~ Collaboration of Equipment & Parts ~

Timeline for lead-free: Set up the schedule for the average manufacturers as follows:

Components: Start supplying components withstand heat resistance / lead-free terminal components: 2001
Complete supplying of lead-free terminal components: 2003
Complete supplying of lead-free components: 2004

Equipment: Start introducing lead-free solder: 2002-2003
Complete lead-free adoption: 2006 (assuming EU-RoHS-2007)

Components: Start supplying components withstand heat resistance / lead-free terminal components: 2001
Complete supplying of lead-free terminal components: 2003

** Whisker (on connectors) occurred, etc*

Complete supplying of lead-free components: 2004

Equipment: Start introducing lead-free solder: 2002-2003

** Low-temperature solder*
** Erosion of solder bath*
** Solder joint of 0.1% Pb, etc.*

Complete lead-free adoption: 2006 (assuming EU-RoHS-2007)

Immediate action is vital

Can these goals be achieved all across Japan by May 2005?!

Emergency Suggestions！！

Purpose

◆To clarify immediate measures against important issues
→ Must be accomplished by December 2004

Important Issues and Immediate Measures

◆ Erosion of solder bath
⇒ Cast bath, static bath, etc.

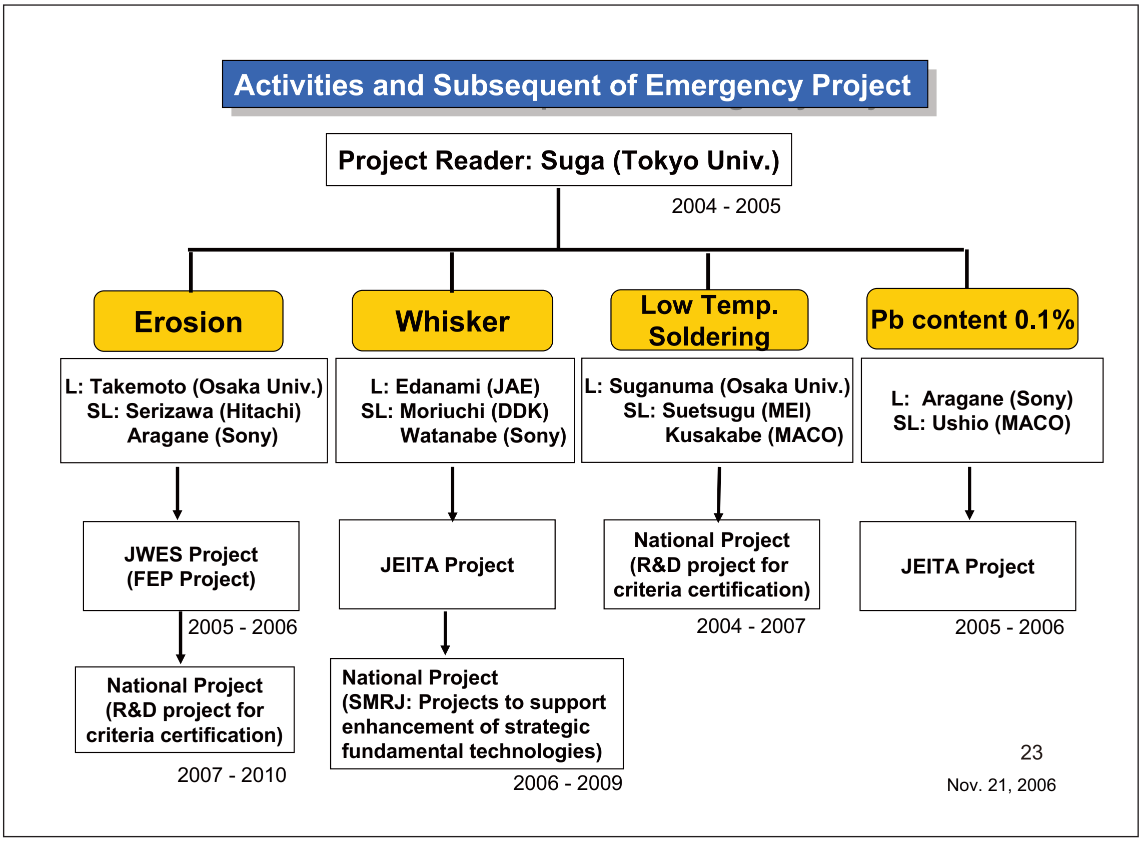
◆Countermeasure against whiskers
⇒ SnBi plating alternative to Au plating, etc.

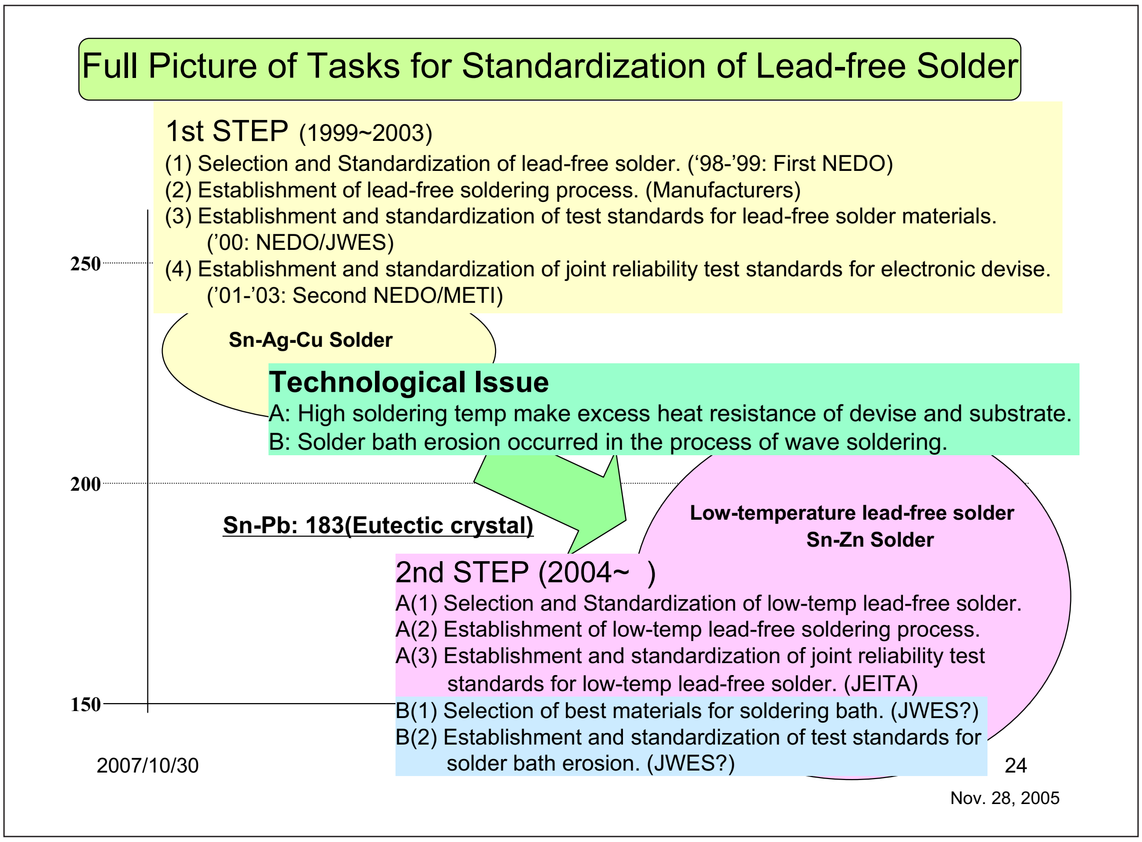
◆ Low-temperature solder
⇒ Aiming at 190° C Zn/Bi/In solder, etc.

◆ Solder joint having 0.1 % Pb content
⇒ High-precision Pb detector, 100% Pb-free plating, etc.

Schedule

◆ Emergency symposium in October, debriefing session for immediate measures will be held in December 2004.


Activities and Subsequent of Emergency Project
Project Reader: Suga (Tokyo Univ.)
2004 - 2005
Erosion
Whisker
Low Temp. Soldering
Pb content 0.1%
L: Takemoto (Osaka Univ.)
SL: Serizawa (Hitachi)
Aragane (Sony)
L: Edanami (JAE)
SL: Moriuchi (DDK)
Watanabe (Sony)
L: Suganuma (Osaka Univ.)
SL: Suetsugu (MEI)
Kusakabe (MACO)
L: Aragane (Sony)
SL: Ushio (MACO)
JWES Project
(FEP Project)
2005 - 2006
JEITA Project
National Project
(R&D project for
criteria certification)
2004 - 2007
JEITA Project
2005 - 2006
National Project
(R&D project for
criteria certification)
2007 - 2010
National Project
(SMRJ: Projects to support
enhancement of strategic
fundamental technologies)
2006 - 2009
23
Nov. 21, 2006


Full Picture of Tasks for Standardization of Lead-free Solder
1st STEP (1999~2003)
(1) Selection and Standardization of lead-free solder. ('98-'99: First NEDO)
(2) Establishment of lead-free soldering process. (Manufacturers)
(3) Establishment and standardization of test standards for lead-free solder materials.
('00: NEDO/JWES)
(4) Establishment and standardization of joint reliability test standards for electronic devise.
('01-'03: Second NEDO/METI)
250
Sn-Ag-Cu Solder
Technological Issue
A: High soldering temp make excess heat resistance of devise and substrate.
B: Solder bath erosion occurred in the process of wave soldering.
200
Sn-Pb: 183(Eutectic crystal)
Low-temperature lead-free solder
Sn-Zn Solder
2nd STEP (2004~)
A(1) Selection and Standardization of low-temp lead-free solder.
A(2) Establishment of low-temp lead-free soldering process.
A(3) Establishment and standardization of joint reliability test
standards for low-temp lead-free solder. (JEITA)
150
B(1) Selection of best materials for soldering bath. (JWES?)
B(2) Establishment and standardization of test standards for
solder bath erosion. (JWES?)
2007/10/30
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Nov. 28, 2005

METI Project
Establishment and Standardization of Substrate Technology for Low-temperature Lead-free Soldering

Period: Oct. 2004 – Mar. 2007 + 1year

Organization:

Japan Electronics and Information Technology Industry Association Low-temperature Lead-free Soldering Technology Standardization Research Committee

Reliability Center for Electronic Components of Japan Environmental Test Station

Joint Reliability Test Method Subcommittee
Clarification and standardization of reliability test items.

Low-temperature Lead-free Soldering Process Subcommittee
Clarification and standardization of process conditions.

Dynamic Characteristic Evaluation Method Subcommittee
Standardization and impact assessment of fine joint and void formation.

Target

① Joint reliability test method for low-temp lead-free soldering.
② Solderbility test method for electronic devise responding low-temp lead-free solder.
③ Void acceptance criteria for low-temp lead-free solder joint reliability.
④ Dynamic characteristic evaluation method for the fine connection of low-temp lead-free solder.

K.Suganuma, ISIR, Osaka University

Picture of Operation at Panasonic Factory Solutions

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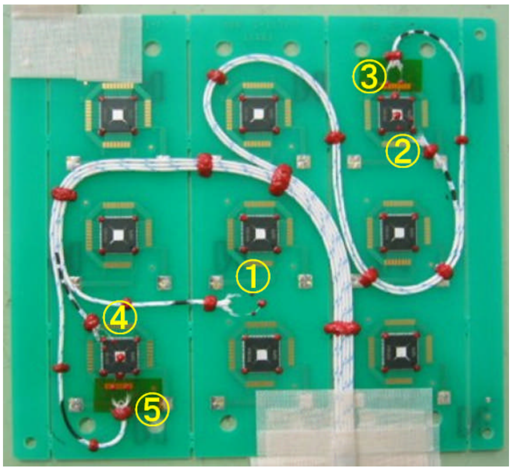

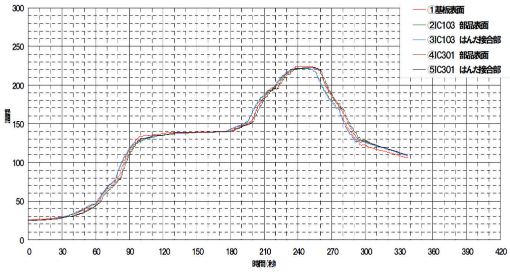

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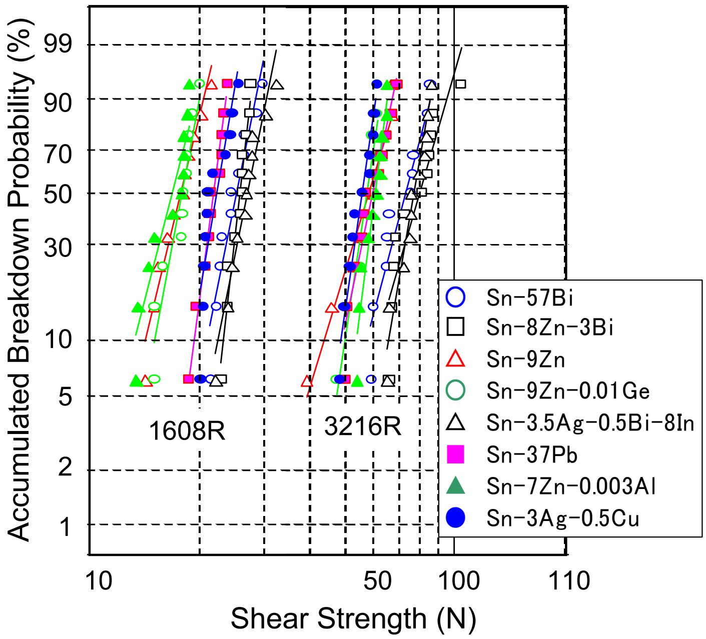
Sample of QFN Mounting Board Layout and Temperature Profile



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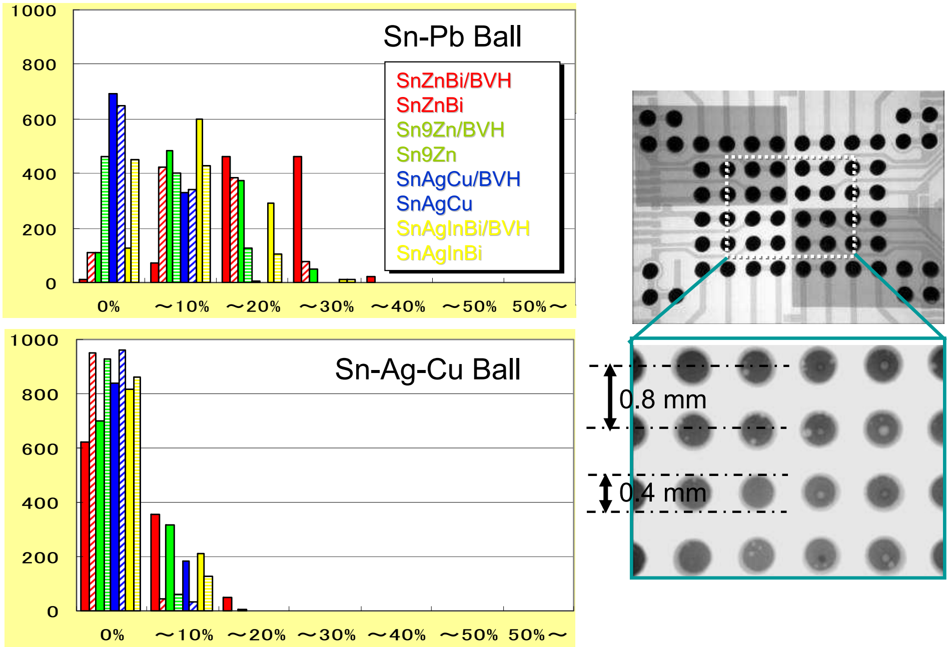
Weibull Plot for Shear Strength of 1608R and 3216R
(Above Cu, with flux, 85℃/85%RH- Approx.1000hours)



Affects of Sn-Ag-Cu ball and Sn-Pb ball on void generation status with BGA mounting. 29
Horizontal scale indicates void area ratio.

Deliverables of METI Project: 「Establishment and Standardization of Substrate Technology for Low-temperature Lead-free Solder」

- JEITA ET-XXXX Selection of the test methods for low-temperature lead-free solder joint durability test method (Provisional)
- IEC60068-2-54: Insertion of reference to low-temperature lead-free solder into the solderability testing of electronic components by the wetting balance method (Draft is in process)
- IEC60068-2-58: Insertion of reference to low-temperature lead-free solder into the test methods for solderability, resistance to dissolution of metallization and to soldering heat of surface mounting devices (SMD) (Draft is in process)
- 91/707/CD: IEC61193-5 Evaluation criteria for voids in soldered joints of BGA and LGA
- 91/695/CD: IEC 62137-1-5, Ed. 1: Surface mounting technology - Environmental and endurance test methods for surface mount solder joints - Part 5: Mechanical shear fatigue test

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SMRJ: Projects to support enhancement of strategic fundamental technologies

『Development of Whisker Prevention Technology for Reliability Improvement of Electronic Mounting』

Osaka Univ. Kastuaki Suganuma

Target

- ✓ Fundamental measure with Sn whisker mechanism analysis
- ✓ Persuade world with fundamental principle
- ✓ Make Japan's first whisker prevention technology to the world standard
- ✓ Provide prevention technology in set with evaluation technology
- ✓ Safety design with reliability evaluation technology and standards

→ World's de facto standard

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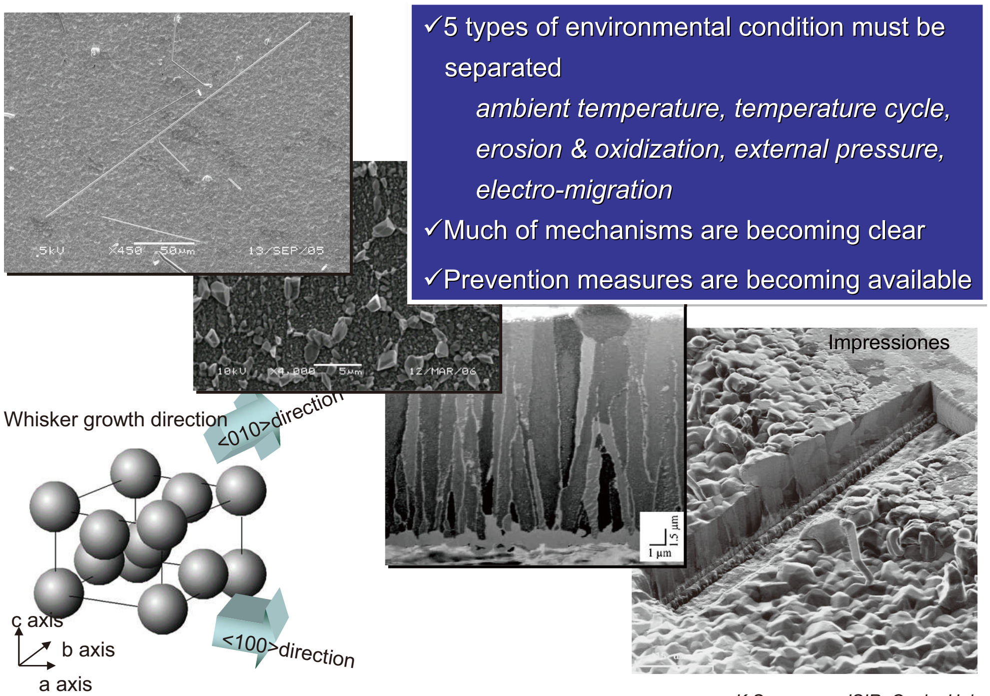
Sn Whisker Formation Mechanism & Prevention

✓5 types of environmental condition must be separated

ambient temperature, temperature cycle, erosion & oxidization, external pressure, electro-migration

✓Much of mechanisms are becoming clear

✓Prevention measures are becoming available



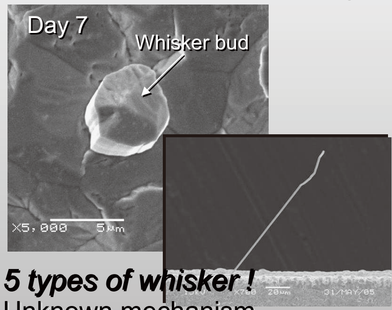
K.Suganuma, ISIR, Osaka University

Whisker is a World's Longstanding Problem

- Conventionally: Whisker bud observed in 1 week → grow to 100 μm in a few months
- Whisker prevents lead-free promoting !
- Unclear mechanism
- Sn plating varies in ambient temperature →analysis method is not established
- Sn alloy is recommended in Japan ⇔ Pure Sn is recommended in Europe and the U.S..

→Pure Sn was chosen in Asia !

Limit of conventional technique



5 types of whisker !
Unknown mechanism,
Uncertain measure

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K. Suganuma, ISIR, Osaka University

Implementation structure

Organization for Small & Medium Enterprises and Regional Innovation, JAPAN

↓ Commission

Japan Electronics and Information Technology Industries Association

↓ Recommission

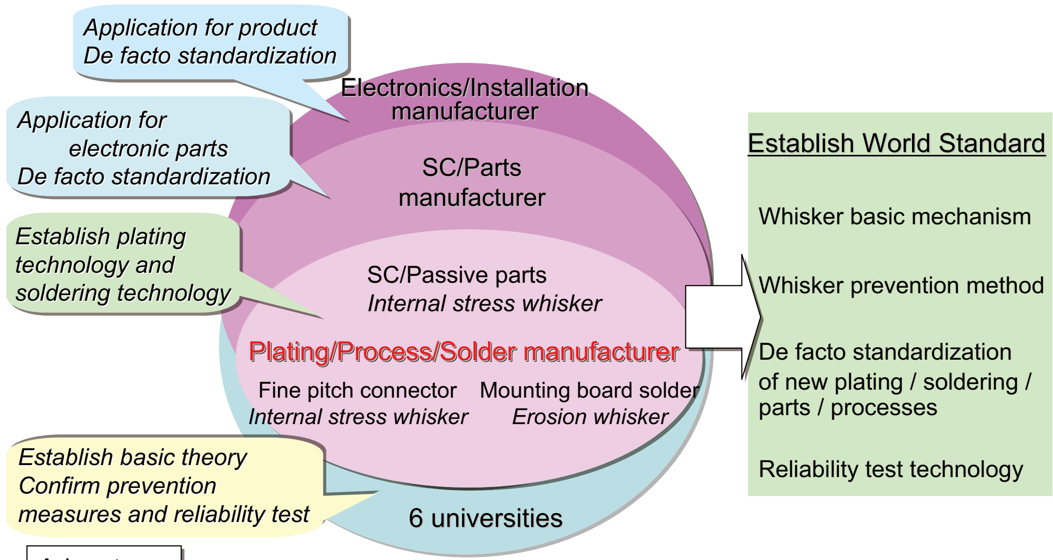
- **Osaka Univ.** Establish plate surface structure analysis technique and study impacts on whisker formation
- **ISHIHARA CHEMICAL** Establish whisker prevention technology by analyzing factors of whisker formation from SC lead frame
- **YUKEN INDUSTRY** Establish whisker prevention technology by analyzing factors of whisker formation from FPC and FFC
- **Nihon Genma Mfg** Establish whisker prevention technology by analyzing factors of whisker formation from lead-free solder
- **EBARA-UDYLITE** Develop whisker prevention measure by clarifying relation between welding condition and crystal orientation of whisker formed on electronic capacitor
- **NISHIHARA RIKOH** Prototype line of plate mass-production for optimization of plate condition and establishment of whisker prevention technology at mass-production level

Technical Support — Tohoku Univ., Yokohama National Univ., Tokai Univ., Kyusyu Univ., Kumamoto Univ. Basic mechanism analysis

Technical Support — Electronic devises/parts manufacturer. Establish reliability test standard and test method

K. Suganuma, ISIR, Osaka University

R&D for 『Development of Whisker Prevention Technology』



Advantage

Certified upstream company, middle electric parts company, downstream user company and universities are forming consortium competitive with Industry-government-academia cooperation, and forming complete supply chain.

Flow of R&D for『 Development of Whisker Prevention Technology 』

Whisker formation mechanism and prevention method (Mainly university)

1. Clarify whisker formation mechanism
2. Standardize whisker acceleration test method (Temperature, humidity and other test conditions)
3. Prevention mechanism proposal

Establish plating condition to prevent whisker (Drug maker)

1. Consider plating solution and chemical composition of solder
2. Optimization of plating conditions and mounting conditions (Film thickness, current density, solution agitation conditions, substrate process, alloy concentration, flux, etc.)
3. Before and after treatment of plating

Whisker prevention management technology at mass-production level (Process/Parts manufacturer)

1. Apply for prototype mass-production level
Studies toward mass-production by evaluating actual sized samples
2. Plating solution manufacturers perform evaluation with common condition using standard plating machine

Reliability test standard and technology, forming de facto standard (Setting, altogether)

1. Establish whisker evaluation depending on application and growth acceptance standard
2. Establish evaluation formula for machine life and its test method with various whisker

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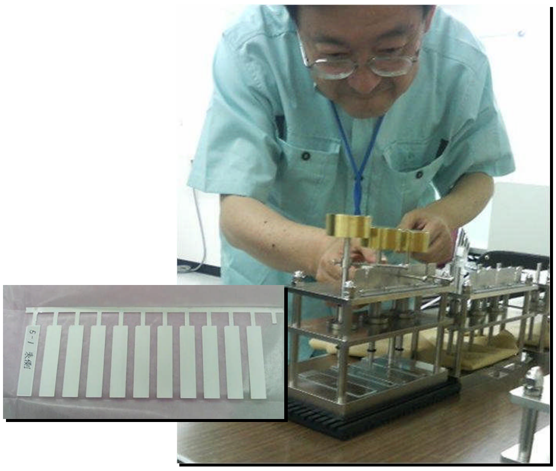
K. Suganuma, ISIR, Osaka University

Picture of Experiment and Development Work

High-resolution SEM observation



External stress type whisker test sample
(put into SEM, directly observable)

Internal stress type whisker test sample
(put into SEM, directly observable)

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K. Suganuma, ISIR, Osaka University

Implementation System of METI Project: 「Standardization of Evaluation Test Method for Damage Suppression Technology of Lead-free Wave Soldering Machine」('07-'09)

Japan Electronics and Information Technology Industry Association Solder Bath Damage Suppression Technology Standardization Research Committee

- **Materials and Mechanism Subcommittee**
- **Surface Finishing Subcommittee**
- **Life Evaluation Subcommittee**

Reliability Center for Electronic Components of Japan Environmental Test Station

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06/07/11,14 JEITA鉛フリー化成果報告会

JEITA Standardization of Second Generation Lead-free Wave Soldering Alloy

JEITA Second Generation Wave Soldering Alloy Standardization PG

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Group Member

Panasonic

SMIC Senju Metal Industry Co., Ltd.

your partner for soldering solution NIHON SUPERIOR

SHARP

kester CONNECTING INNOVATION

TOPY NIPPON FILLER METALS LTD.

FUJITSU

TAMURA

株式会社ニホンゲンマ NIHON GENMA MFG. CO.,LTD.

OKI

NIHON HANDA

HITACHI Inspire the Next

muRata Innovator in Electronics

TOSHIBA

協和電線株式会社（古河電工グループ）

SONY

Victor・JVC

Cookson Electronics

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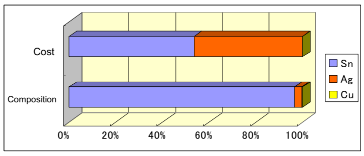
Expectation for the Second Generation Wave Alloy

Problems of conventional solder (Comments from preparation meeting)

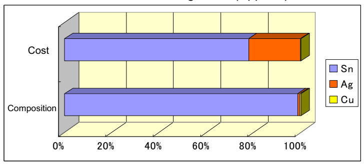
- Escalating price of main material
- Copper-tin type is unsuitable for through-hole
- Problem of copper foil erosion

"Cost is the most important key factor"



Cost structure of Sn3Ag-0.5Cu(Approx.)

Need for the second generation wave soldering



Cost structure of Sn1Ag-0.5Cu(Approx.)

「Low cost material suitable for all products
except for the products requiring Sn-3.0Ag-0.5Cu」

Users can decide by themselves if lost characteristics could be quantified

e.g.

- •Surface gloss ・・・・・ Matt finish is available
- •Through-hole ・・・・・ Small dimples could be accepted
- •Copper erosion ・・・・・ No problem in normal operation
- •Dross ・・・・・ Equal to Sn-3.0Ag-0.5Cu in normal operation
- •Operation temp. ・・・・・ 255℃ as a maximum (Heat resistence limit of parts)
- •Cost reduction ・・・・・ 20% or more of Sn-3.0Ag-0.5Cu (Ag1% = 10% costs)

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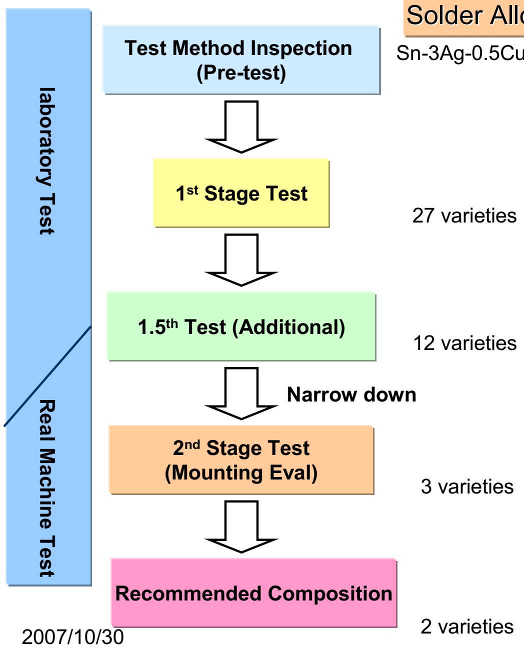
Test Flow



Solder Alloy

Sn-3Ag-0.5Cu: Ref

Proposal of Solder

I. Many proposed compositions from solder manufacturer
Patent: regardless of whether or not compensation is received, it should be opened at a fair and reasonable cost
II. Narrow down composition candidates by static characteristic test
(Testing all proposed compositions with real machine is unrealistic)

Test

1. Divide static characteristic (laboratory test) and dynamic characteristic (real machine test)
2. Static characteristic test
   I. Evaluate necessary characteristics for wave with alternative characteristics
   II. Same results should be obtained anytime anywhere
3. Dynamic characteristic test
   I. Evaluate dynamic characteristics and working property using actual substrate and production line

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Conclusion

- SAC0307 is excel in the balance of low cost and wettability
  As wettability obviously deteriorates, it should be premised that the minimum operating temperature is 250 ℃, the minimum primary water immersion time is 1.5sec, and using machine with a temperature control of ±2.5 ℃ which enables to keep margin in parts damaged condition. It should be introduced after evaluated individually as it has little deterioration of heat shock resistance. Adequate fabrication yield is promised by choosing sufficient flux, but it is difficult to achieve 100% TH finish.
- SAC107 has an advantage with its balance of wettability and heat shock resistance. Though it has close characteristics with SAC305 on the same installation condition with SAC0307 as described above, there are great difference of wettability at high heat area. Individual corrugated set up shall be done as the bridge performance of lead parts is inferior to SAC307.

- Above-mentioned 2 compositions
  1. SAC107
  2. SAC0307

  are recommended as next standard.

- For minor addition element with purpose
  - P: Decrease dross generation
  - Ni: Decrease copper erosion

  are accepted as optional. However, upper limit management appropriate for each operating temperature is vital as it has side-effects.

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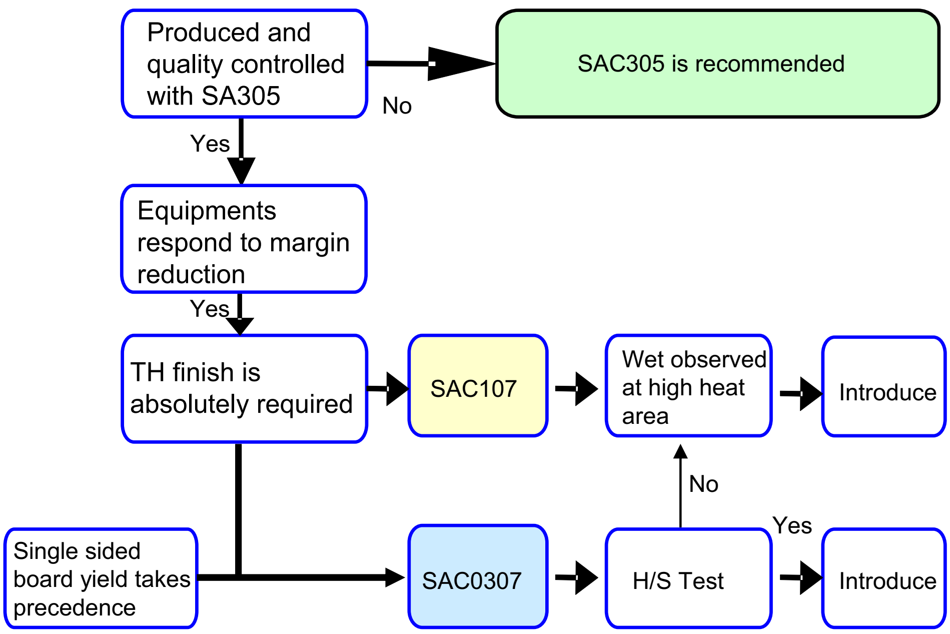
Recommended Alloy Selection Method



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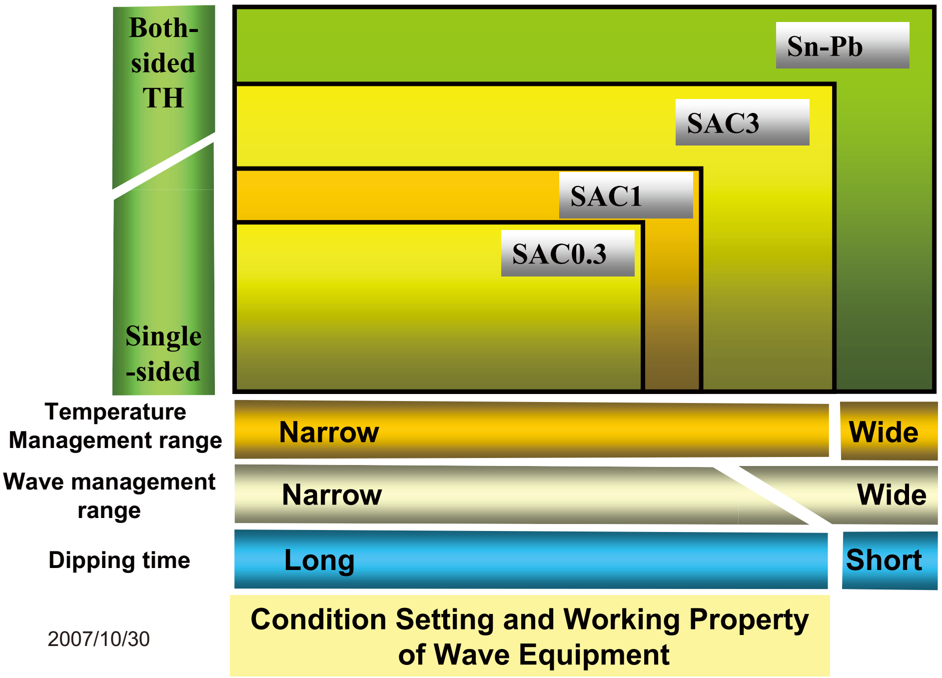
Change of Mounting Process Window (Image)



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Thank you for your attention.

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Consideration of RoHS issues and Tin Whiskers Evaluation in JAXA

October 30th, 2007

Safety and Mission Assurance Department
Electronic, Mechanical Components and Materials Engineering Group
Japan Aerospace Exploration Agency (JAXA)

Contents

1. Background
2. Effects of RoHS in the Consumer Market
3. Community
4. Whiskers Evaluation in a Vacuumed Chamber
5. Summary

1. Background

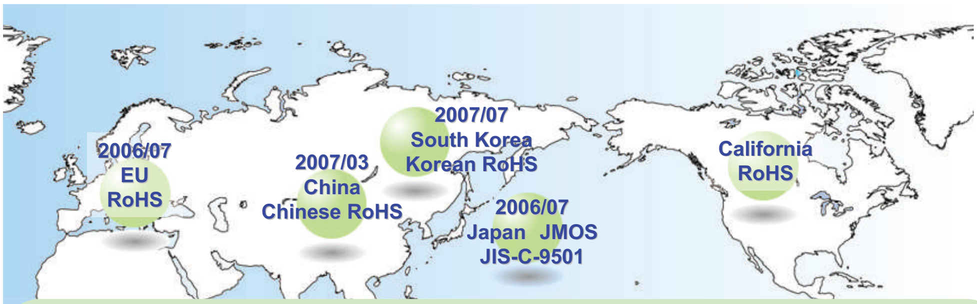
The EU has enacted two directives, RoHS and WEEE, that prohibit the use of Pb, Cd, Cr^{6+}, Hg, PBB and PBDE in products for the EU consumer market since July 2006. One of the key elements in these directives is Pb, which had been widely used in electric components such as solder and parts terminations. Although these regulations only affect products for sale in the EU, many manufacturers in the world have shifted to lead-free products.

1. JAXA continues to use parts containing SnPb for space applications.
2. Purchase of the parts and materials that contain lead is becoming difficult.
3. Reliability problems of lead-free parts and materials may surface in space applications.

***1:RoHS(Restriction of the use of certain Hazardous Substance in electrical and electronic equipment)**：
http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_037/l_03720030213en00190023.pdf
WEEE(Waste Electrical and Electronic Equipment)：
http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_037/l_03720030213en00240038.pdf

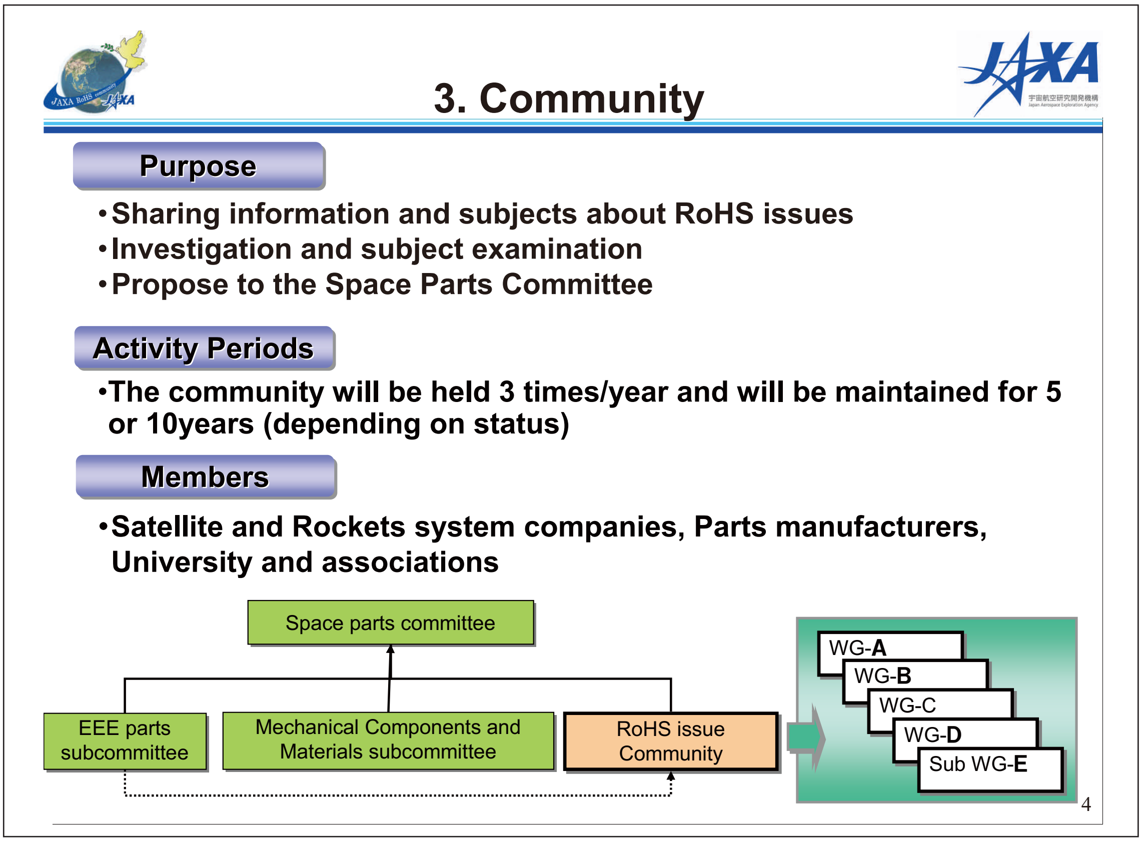
2

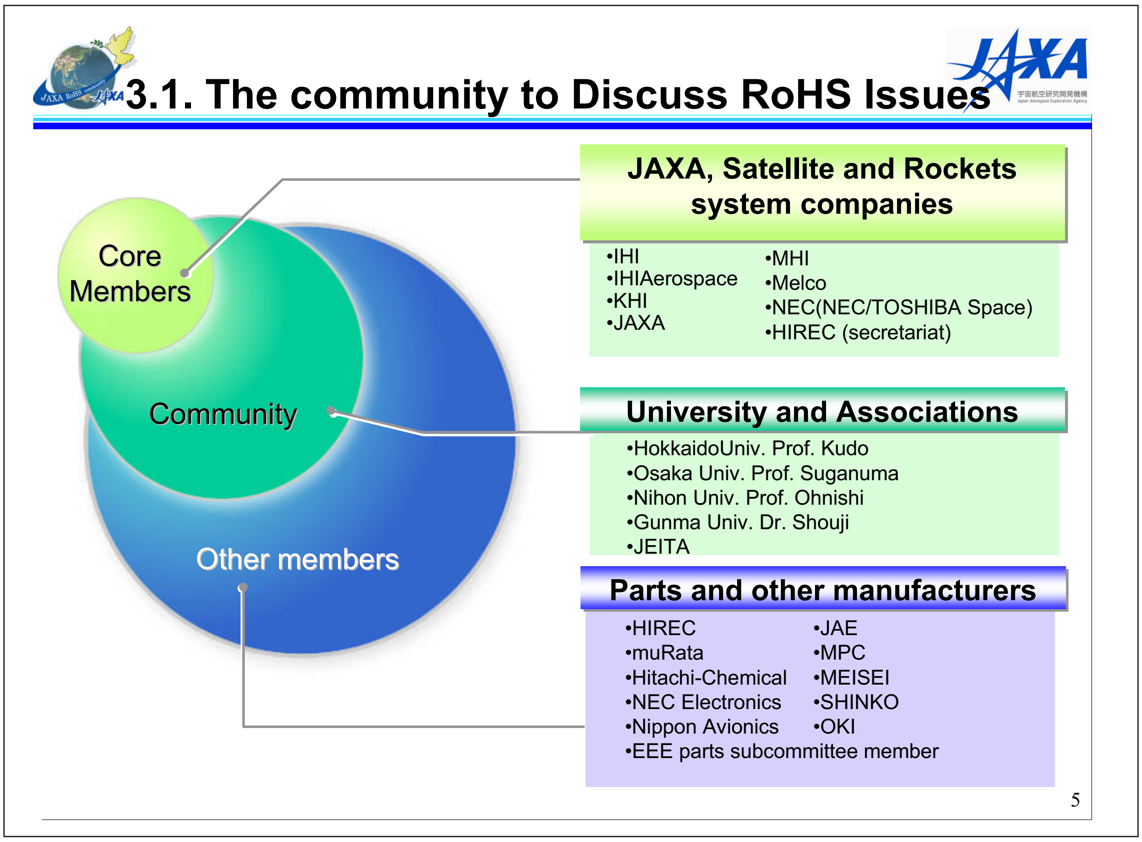
2.Effects of RoHS in The Consumer Market



- RoHS & WEEE directives prohibit the use of lead in consumer products in EU after July 2006.
- In several states in the U.S., a similar "green" law has enacted.
- In China and Korea, a similar directive to RoHS was enacted in March 2007.
- Many parts manufacturers in the world have shifted to lead-free products.
- In Japan, "JIS C 0950; J-MOSS" that is not similar to RoHS was enacted in Dec. 2005.
- J-MOSS does not prohibit the use of lead, but requires to indicate the usage of lead.
- Many Japanese parts manufacturers also shifted to lead-free products.

3


3. Community
Purpose
•Sharing information and subjects about RoHS issues
•Investigation and subject examination
•Propose to the Space Parts Committee
Activity Periods
•The community will be held 3 times/year and will be maintained for 5 or 10years (depending on status)
Members
•Satellite and Rockets system companies, Parts manufacturers, University and associations
Space parts committee
EEE parts subcommittee
Mechanical Components and Materials subcommittee
RoHS issue Community
WG-A
WG-B
WG-C
WG-D
Sub WG-E
4


3.1. The community to Discuss RoHS Issues
Core Members
Community
Other members
JAXA, Satellite and Rockets system companies
•IHI
•IHIAerospace
•KHI
•JAXA
•MHI
•Melco
•NEC(NEC/TOSHIBA Space)
•HIREC (secretariat)
University and Associations
•HokkaidoUniv. Prof. Kudo
•Osaka Univ. Prof. Suganuma
•Nihon Univ. Prof. Ohnishi
•Gunma Univ. Dr. Shouji
•JEITA
Parts and other manufacturers
•HIREC
•muRata
•Hitachi-Chemical
•NEC Electronics
•Nippon Avionics
•JAE
•MPC
•MEISEI
•SHINKO
•OKI
•EEE parts subcommittee member
5

3.2. Working Group

Community — Chairperson : Dr. Hasegawa（JAXA S&MA）

- **WG- A** — Mixed Assemble tech. : **NEC/TOSHIBA Space**
  - **A1** Rockets : Subjects, Evaluation, Discussion
  - **A2** Satellite : Subjects, Evaluation, Discussion
- **WG- B** — Pb-free trend survey and lead tech. : **HIREC**
  - **B1** Trend survey of Pb-free parts and material
  - **B2** Hot Solder Dip method evaluation
- **WG- C** — Pb-Free Assemble tech. : **Melco**
  - Pb-free parts, material, assembly techniques
- **WG- D** — Whiskers evaluation : **Osaka Univ.**
  - Whiskers mechanism, evaluation method, accelerated test method
- **Sub-WG-E** — Other prohibited material : **TBD**
  - Lead, Cadmium, Chromium

6

4. Whiskers Evaluation in Vacuumed chamber

【Background】

- SnPb Hot Solder Dip (HSD) mitigates Sn whiskers growth.
- Sn oxide formation is one of the root cause of the whisker growth.
- In the orbit satellite, electrical components will be in vacuum condition.

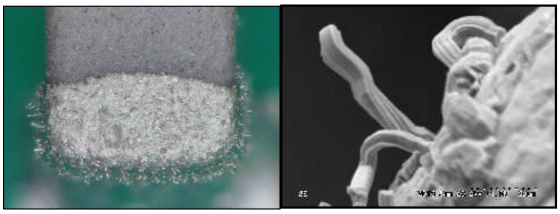


Fig. 1 Whiskers on chip capacitor

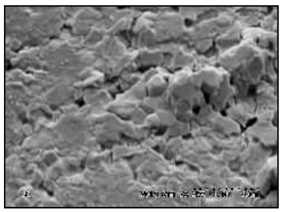


Fig.2 after HSD sample

【Purpose】

•To evaluate Vacuum condition mitigates whiskers growth.

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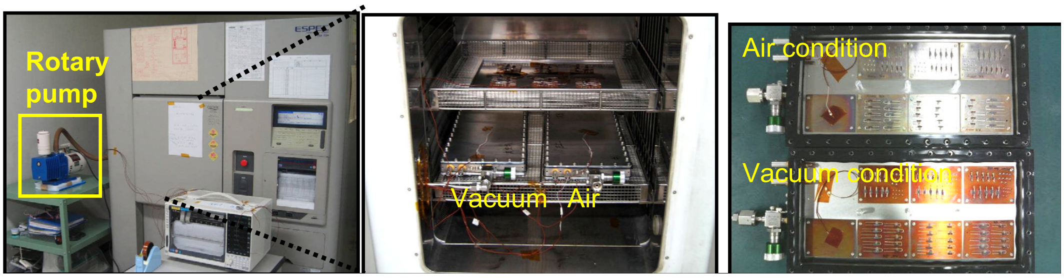
4.1. Test condition

Test condition

Test method : Thermal shock cycling
Temperature cycling : up to 2,000 cycle
Temperature range : -40 to +125 deg. C
Soak time : 60 minutes
Atmosphere : Vacuum (3Pa), Air
Sample : 2 type chip ceramic capacitor (Electrode is pure Tin)

Test Equipment @TKSC



4.2. Summary of Vacuum and Air condition test

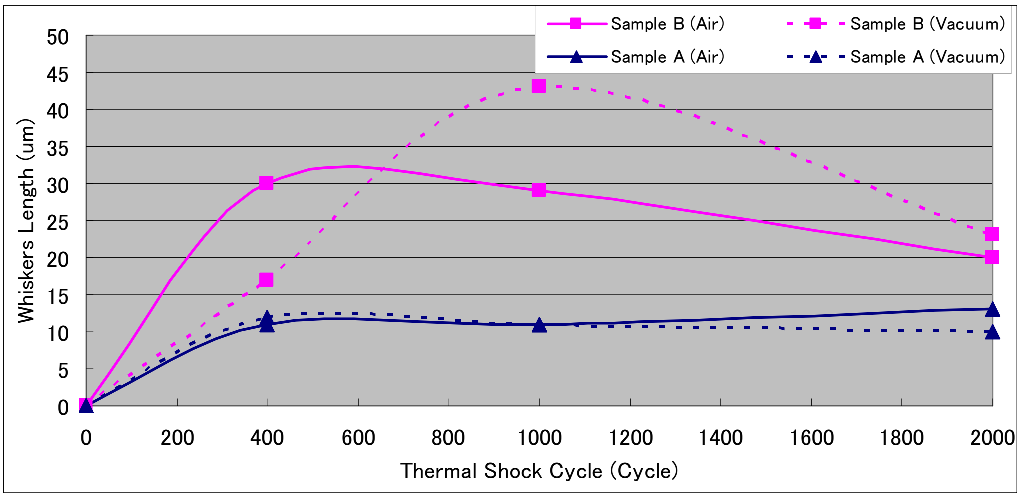
Visual and SEM inspection results

Sample Type	Condition	Thermal shock cycle 0	147	420	1,040	2,000
Sample A	Vacuum	○	×	××	××	××
	Air	○	×	××	××	××
Sample B	Vacuum	○	×	××	××	××
	Air	○	×	××	××	××

※ ○ : Whiskers were not observed
× : Whiskers were observed
×× : Whiskers were increased

4.3. Whisker length

Whiskers Length Result



- **Whiskers length were almost same in air and vacuum condition.**
- **Whiskers length were saturated at 2,000 cycle thermal shock.**

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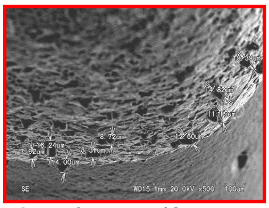
4.4. SEM inspection result (1/2)

Sample A

500 times

Vacuum



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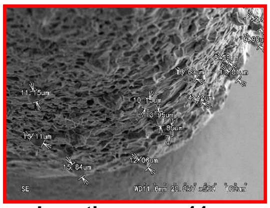

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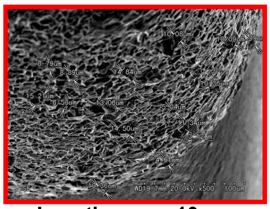

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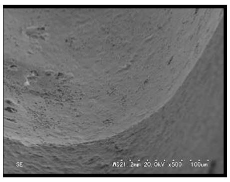
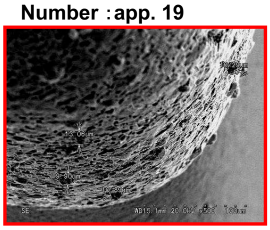


Air



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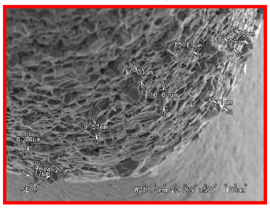
Number :app. 12



Length :ave. 11um
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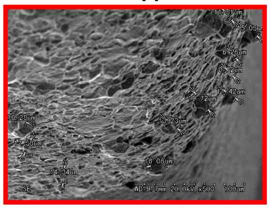
Number :app. 18



Length :ave. 13um
:max. 19.72um
Number :app. 11

0 cycle | 420 cycle | 1,040 cycle | 2,000 cycle

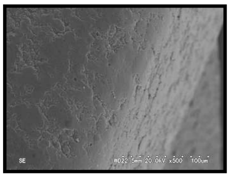
11

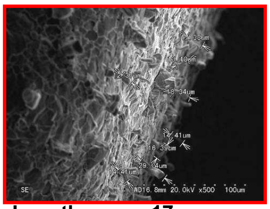
4.4. SEM inspection result (2/2)

Sample B

500 times

Vacuum





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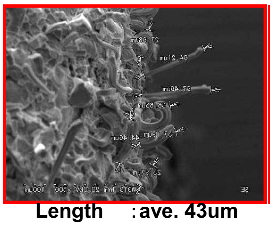

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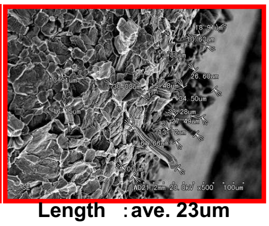

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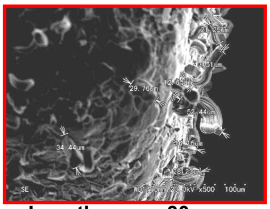
Air



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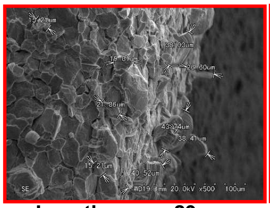

Length :ave. 29um
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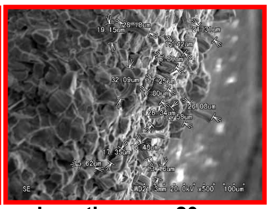
Number :app. 15



Length :ave. 20um
:max. 32.09um
Number :app. 16

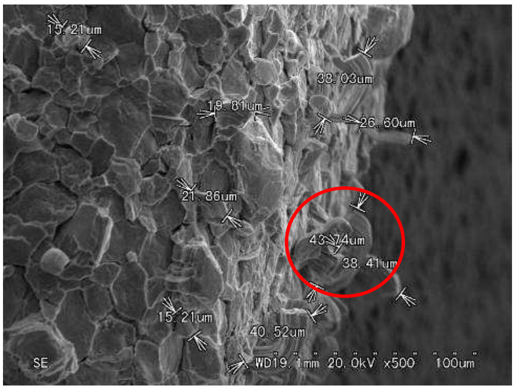
0 cycle | 420 cycle | 1,040 cycle | 2,000 cycle

12

4.5. Comparison of whiskers shape

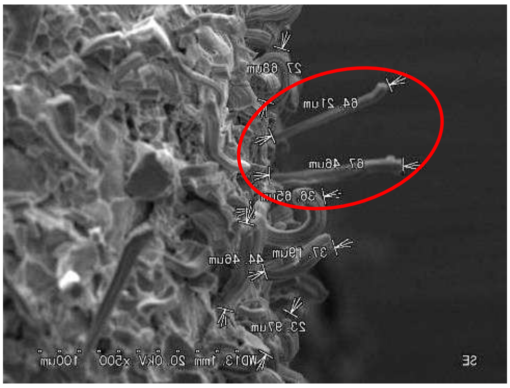
Sample B at 1,040 cycle

500 times



Air Condition

Length :ave. 29um
:max. 43.74um
Number :app. 15



Vacuumed condition

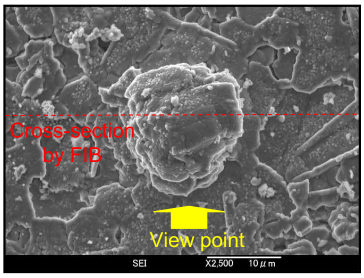
Length :ave. 43um
:max. 67.46um
Number :app. 21

•Whiskers shape growth in vacuumed condition is narrow

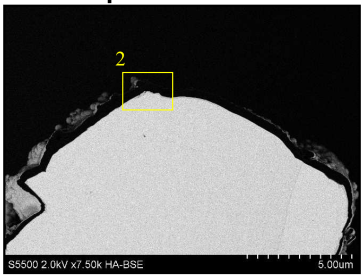
13

4.6. Whisker Cross-Section (1/2)

Whisker cross-section（sample A, Air condition, after 1,040 cycle）

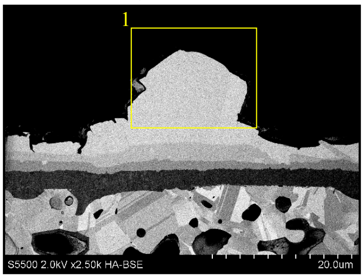


Close-up of #1 area

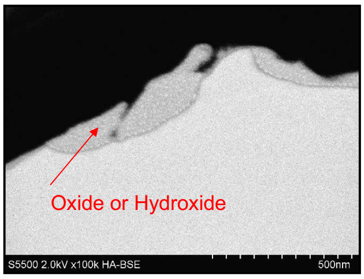


1.Around the whisker, Sn was disappeared.
2.Whisker was growing at grain division

Cross-section



Close-up of #2 area

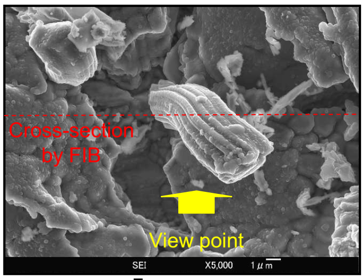


Surface of whisker, oxide or hydroxide was observed.

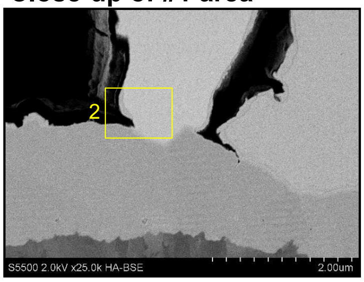
14

4.6. Whisker Cross-Section (2/2)

Whisker cross-section（sample B, Air condition, after 1,040 cycle）

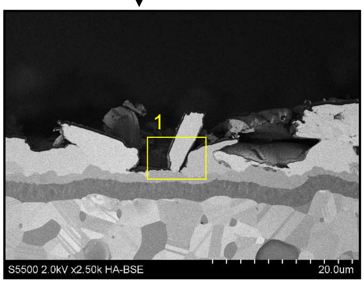


Close-up of #1 area

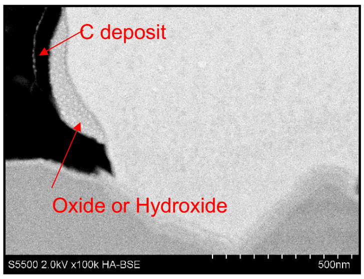


1.Around the whisker, Sn was disappeared.
2.Whisker was growing at grain division

Cross-section



Close-up of #2 area



Surface of whisker, oxide or hydroxide was observed.

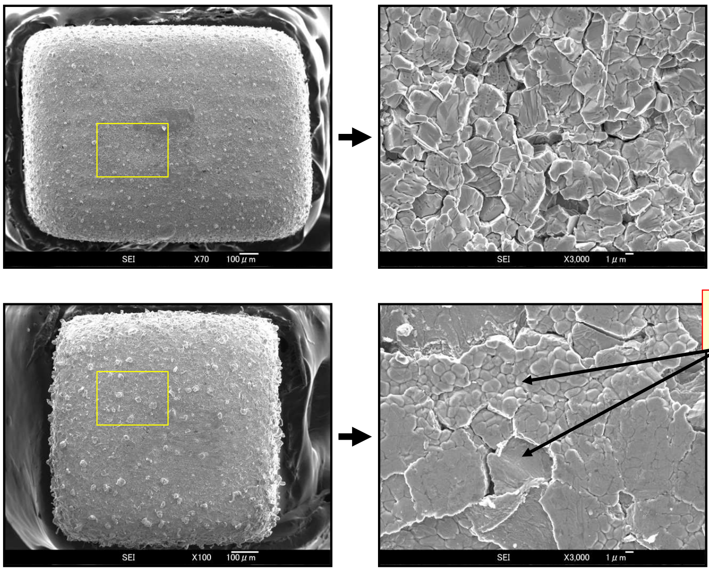
15

4.7. Comparison of Electrode Condition

SEM image (after 1,040cycle thermal shock)

Sample A

Sample B



Grain size is uniformed

Grain size is not uniformed

16

5. Summary

EU enacted RoHS and WEEE directives, that restrict the use of Pb et.al. for EU consumer products after July 2006.

1. Purchase of the parts and materials that contain lead will be becoming difficult even for space parts.
2. JAXA established the community to discuss RoHS issue.
3. Whiskers characteristics is slight different in vacuum and air condition.

Whiskers evaluation method and mitigate risk method will be discussed at the community.

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The 20th Microelectronics Workshop at Tsukuba

Wrap-up Report

Oct. 30, 2007
Takashi Tamura
Electronic, Mechanical Components and Materials Engineering Group
Institute of Aerospace Technology(IAT), JAXA

1

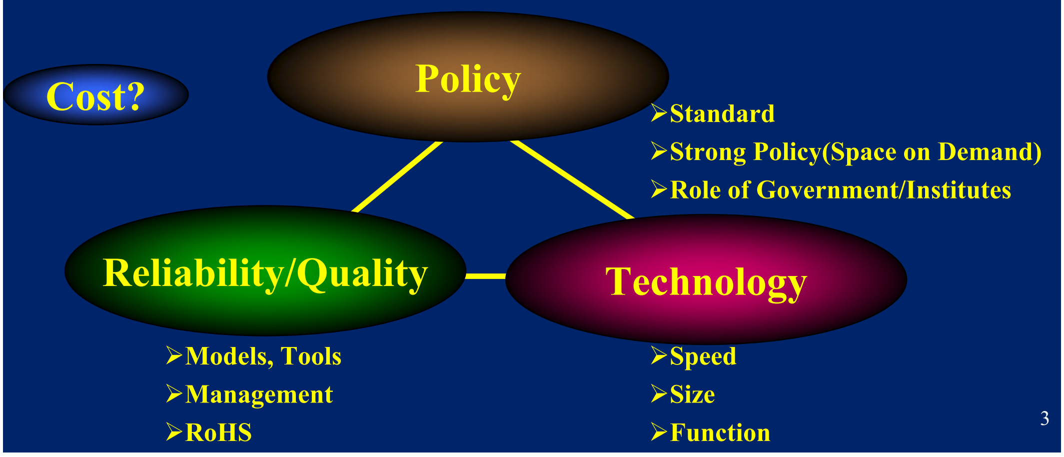
Overview

0.Introduction
1.Reliability/Quality Assurance
2.Strategy to Use Commercial Parts
3.Advanced Technology :MEMS, GaN
4.RoHS
5.EEE Parts Development in Japan
6.Conclusions

2

Introduction

Theme:
Current Status and Future Prospect of Commercial Components, Materials and Technologies in Space Applications
「民生用部品・材料・技術の宇宙転用の現状と今後」



3

1.Reliability/Quality Assurance

Issues on Electronic Parts

- ◆Reliability Verification
- ◆Design(Ground Applications)
- ◆Obsolescence/Change Process Control
- ◆User Notification
- ◆Long Term Storage
- ◆Lot Homogeneity
- ◆Counterfeit

Many Issues!

➢Quality Assurance by D&D
➢3 GEN Principle
(Genba, Genbutsu, Genjitsu)

Space Industries should :
- ◆ **Collect/Share necessary information worldwide**
- ◆ **Know Genba(Actual Place)**
- ◆ **Know Genbutsu(Actual Thing)**
- ◆ **Know Genjitsu(Actual Situation)**

4

2.Strategy to Use Commercial Parts

COTS Parts Evaluation in SERVIS Project

Type	Quantity	Cost Breakdown
CPU, Memory, GA	250	87%
Digital IC	2,530	2%
Semiconductor	6,720	1%
Resister, Capacitor	14,600	2%
Solar Cell, Relay, etc.	13,800	8%
Total	37,900	100%

CPU/Memory/GA are the main contributor

About 60% of ground-tested COTS can be used for LEO (low earth orbit) satellites after evaluation

COTS Database **COTS Guideline**

5

2.Strategy to Use Commercial Parts

Successful Application of Commercial Parts…..

Europe : ECSS-Q-60B Level 3 COTS
USA :GSFC 311-INST-001
Japan : Guidelines from USEF, Some from JAXA

…. with enough knowledge of each COTS devices.

- **Still Case-by-Case Issue to assure its life, radiation-tolerance, thermal issues, storage environment, etc.**
- **COTS should be treated as "New Technology" for Space Applications.**

Two(2) Different approaches will be possible.

- **Simply Replace Hi-Rel parts with COTS? … seems not promising**
- **Conceptual Change to "Reliability as a Whole System"?**

3.Advanced Technology :MEMS, GaN, etc

Devices for Space Applications:

Small : Launch Capability
Low Power : Limited Power is Available in Space
Long Life :24 Hours, 10, 15 Years or more
Endurance :Radiation, Thermal Cycle

→ MEMS, NANO Devices, WBG(GaN, etc) Devices will play a significant role in the future.

→ MEMS : Inconsistent with Mass-Production?
WBG :Insufficient Evaluation

→ In-House Production or Further Extensive Evaluation Program will be Necessary

4.RoHS

Space Industries Can not Avoid RoHS Issues.

◆"Space" is Exempt from RoHS Directive Now

◆However, Space Industries can not live by itself.

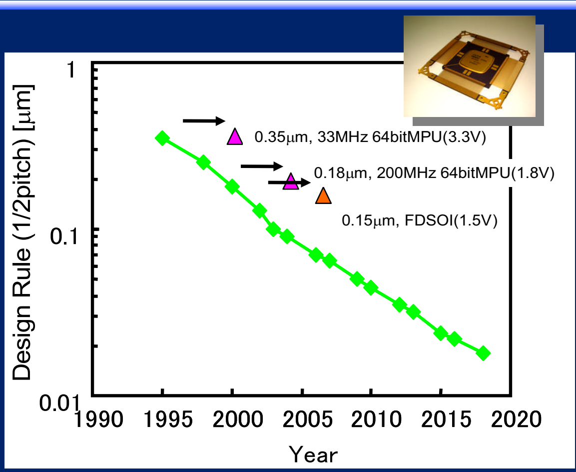
◆We have to know:
- How to maintain lead, etc until when?
- How to mitigate reliability issues using lead-free?
- How to introduce "lead-free"

→ Standardization(GEIA, JEITA, etc.) for
- Test Method of Materials
- Life Evaluation
- Surface Finishing, etc.

will become essential.

8

5.EEE Parts Development in Japan



Design rule trend and JAXA's LSI Roadmap

- **MPU/ASIC/Memory will still be the essential part for "Non-Dependence and Competence.**
- **Introduction of COTS need strong "Policy" and "Extensive Evaluation Program".**
- **Application of MEMS, NANO Devices, WBG(GaN, etc) Devices may Change the Concept of System Reliability as a whole.**

9

6.Conclusions

Government/ Institutions

Space Industries

Parts Manufacturers

Keyword is… "Partnership"

Thank You!

10

5. 閉会挨拶

田村　高志　JAXA 総合技術研究本部　部品・材料・機構技術グループ長

（要旨）

今年で第 20 回という記念すべきタイミングでこの国際会議場でワークショップを開催させていただきました。多くの方々の参加と活発な議論があり大変有益なものとなりました。また展示も 40 ブースという過去最大の規模となり、産学官連携部の協力でいろいろなフィールドの展示がなされ、大変興味深い展示会ができました。

宇宙用部品に対する関心が高まる中、国内のみならず海外も含めた協力の一環として、このワークショップをさらに活発に開けることを期待しています。来年も今年に劣らぬ充実したワークショップとなるよう、進めてまいりたいと思います。

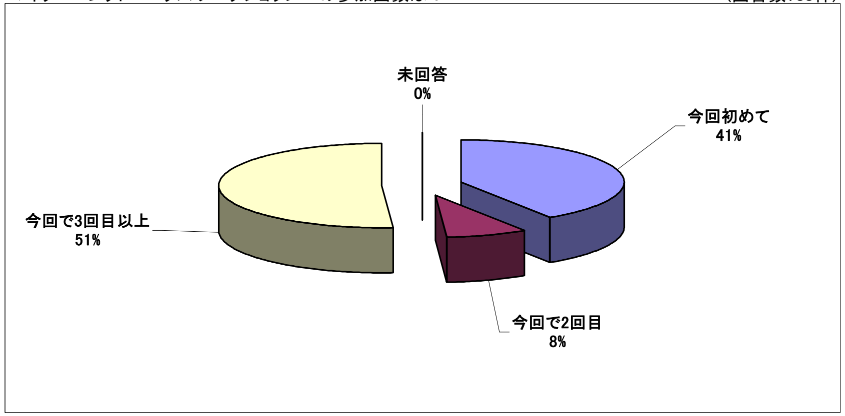
2 日間にわたりどうもありがとうございました。

別紙2
平成19年11月12日作成

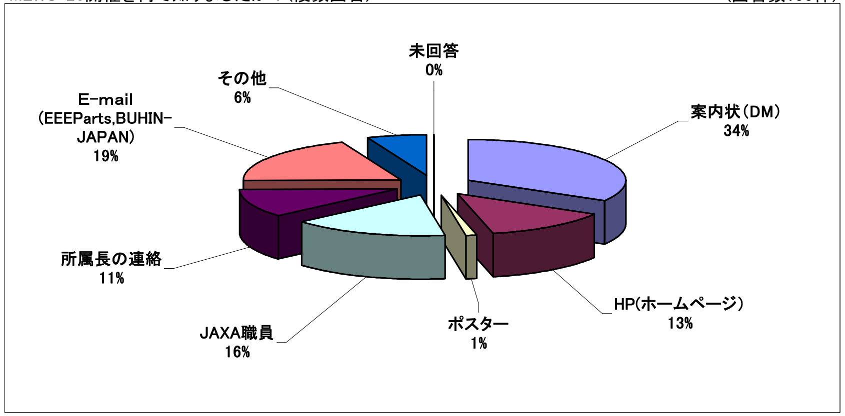
第20回マイクロエレクトロニクスワークショップ(MEWS-20) アンケート調査結果

回答総数88、回収率35%

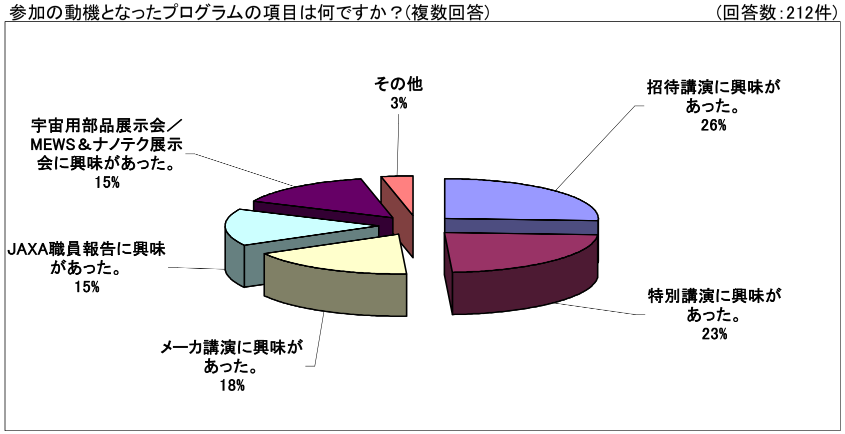
Q1 マイクロエレクトロニクスワークショップへの参加回数は？ (回答数：88件)



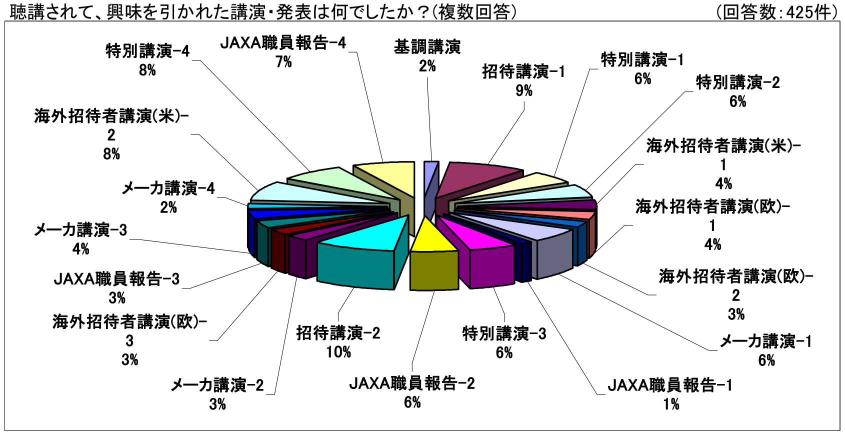
Q2 MEWS-20開催を何で知りましたか？(複数回答) (回答数：99件)



Q3 参加の動機となったプログラムの項目は何ですか？(複数回答) (回答数：212件)



Q4 聴講されて、興味を引かれた講演・発表は何でしたか？(複数回答) (回答数：425件)



順位	興味を引かれた講演・発表ベスト5		占有率
1	招待講演-2	：衛星搭載部品の課題と将来展望	10%
2	招待講演-1	：日産自動車における品質マネジメント	9%
3	海外招待者講演(米)-	：The Development of a NASA Lead-free Policy for Electronics	8%
4	特別講演-4	：日本の鉛フリー化の状況	8%
5	JAXA職員報告-4	：JAXAにおけるRoHS問題の取り組みと錫ウィスカの基礎評価	7%

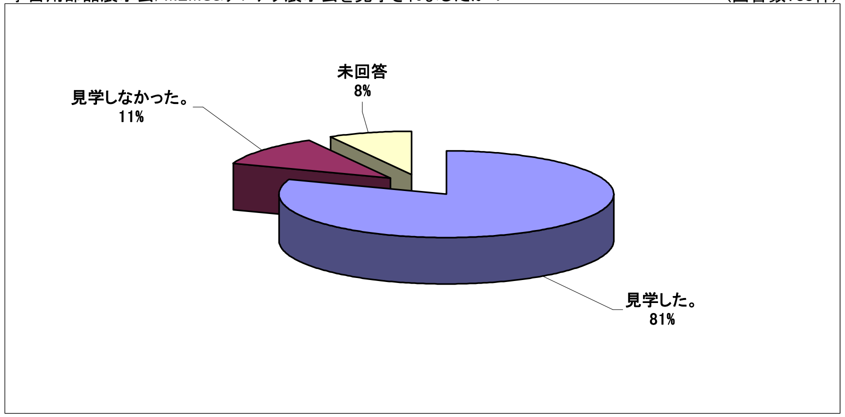
別紙2
平成19年11月12日作成

第20回マイクロエレクトロニクスワークショップ(MEWS-20) アンケート調査結果

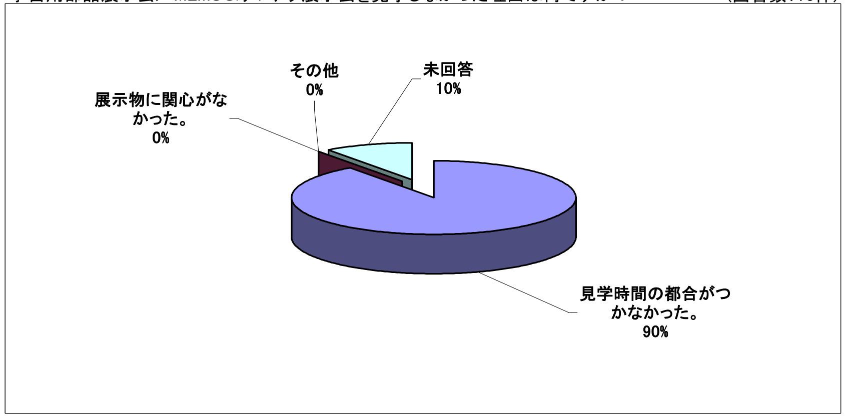
Q5 ワークショップの講演・発表内容に関して、お気づきの点やご感想をお聞かせください。
(主要5項目)
1 話題性のある講演発表でよかった。(6件)
2 質疑応答を含む講演時間を長くして欲しい。(3件)
3 発表資料は日本語と英語の両方を用意して欲しい。(2件)
4 講演者の話し方をもう少しゆっくりとして欲しい。(2件)
5 会場が良かった。(2件)

Q6 今後、どのようなテーマ、どのような内容の講演・発表をご希望ですか？
(主要5項目)
1 部品の故障解析、解析技術、信頼性試験。(8件)
2 宇宙用部品の動向。(6件)
3 COTS部品、PEMSの国内規格化を含む民生部品の宇宙利用について。(3件)
4 実装技術。(3件)
5 部品プログラムの方向。(2件)

Q7-1 宇宙用部品展示会/MEMS&ナノテク展示会を見学されましたか？ (回答数:88件)



Q7-2 宇宙用部品展示会／MEMS＆ナノテク展示会を見学しなかった理由は何ですか？ (回答数:10件)



Q8 展示会で興味をお持ちになった企業又は部品をご記入下さい。

(Q9は欠番)

(宇宙用部品関連)

	企業名(上位5社)	
1	HIREC	5
2	JAXA	4
3	富士エレクトロニクス	3
4	エアロスペースリサーチ	2
5	オーケープリント	2
	計	16

	部品名(上位3品目)	
1	MPU(HIREC)	3
2	プリント板(オーケープリント)	2
3	レギュレータ(エアロスペースリサーチ)	2
	計	7

(MEMS&ナノテク関連)

	企業名	
1	東北大学	3
2	群馬大学	1
3	JAXA	1
4	産業総合技術研究所	1
5	三菱電機	1
6	大学	1
7	MEMS関連メーカ	1
	計	9

	部品名	
1	MEMS・MEMSデバイス	2
2	RF用MEMSデバイス	1
	計	3

別紙2
平成19年11月12日作成

第20回マイクロエレクトロニクスワークショップ(MEWS-20) アンケート調査結果

Q10 展示会に関しまして、お気づきの点やご感想などをお聞かせください。
(主要5項目)
1 多くの出展企業があり非常に参考となった。(5件)
2 展示会場が狭い。もう少しスペースに余裕があると良い。(5件)
3 展示品が少ない印象を受けた。(2件)
4 衛星あるいはロケット又はそのコンポーネントとの関連が分かるように展示できないか。(1件)
5 新規企業が多くなっているが、真の信頼性は大丈夫か？今後の不具合が懸念される。(1件)

Q11 MEWS-20全体に関して、お気づきの点やご感想などをお聞かせ下さい。
(主要5項目)
1 開催会場が良かった。(交通の便、見易さ、広さなど)(13件)
2 午前、午後の途中休憩(コーヒーブレイク)を作ったほうが良い。(6件)
3 前刷集をカラーにして欲しい。(6件)
4 ワークショップから懇親会までの時間が長い。(3件)
5 最寄駅から会場までの道筋に案内板、会場内廊下にわかりやすい案内表示があるとよい。(3件)

－以上－

画像紹介

開会の挨拶●坂田　公夫（JAXA）

Workshop（1日目）

Workshop（1日目）

講演風景（講演順）


山本　昭男（JAXA）


北澤　宏（日産自動車株式会社）


佐伯　徳彦（経済産業省）


秋山　雅胤（財団法人　無人宇宙実験システム研究開発機構）


Jeffrey H Sokol (The Aerospace Corporation)


Franck Davenel (French Ministry of Defense)

講演風景（講演順）


Juergen Tetzlaff (German Aerospase Center)


Geoffrey Penhaligon (IGG Component Technology Ltd,)


吉川　健太郎（JAXA)

Workshop（２日目）

講演風景（講演順）


三田　信（JAXA）


荒川　哲人（JAXA）


藤本　直伸（三菱電機株式会社）

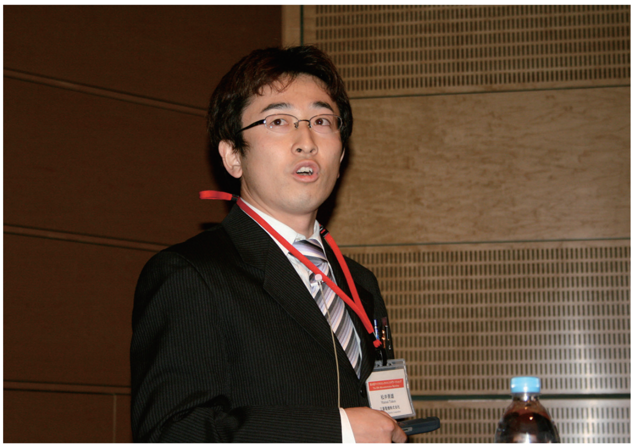

堀田　孝章（立山科学工業株式会社）


Andrew Robert Barnes (European Space Agency)


新藤　浩之（JAXA）

講演風景（講演順）


久野　真一 (Aeroflex Colorado Springs Agency)


松井　崇雄（三菱電機株式会社）

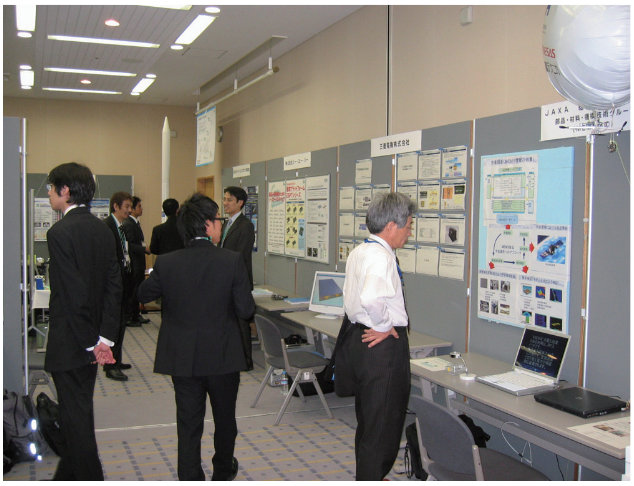

Michael J Sampson (NASA)

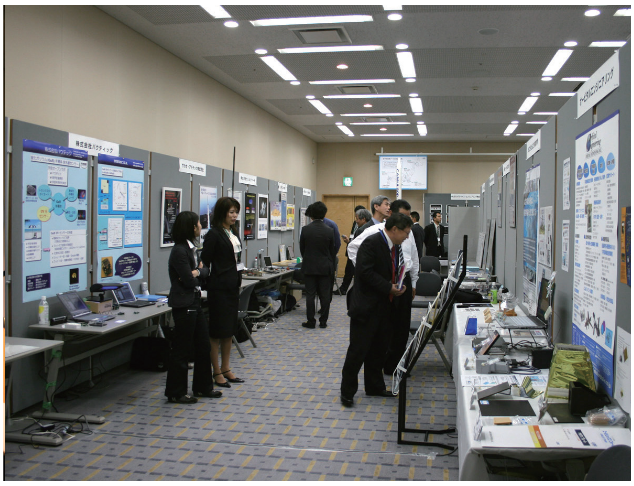

山本　克己（テクノオフィスヤマモト）

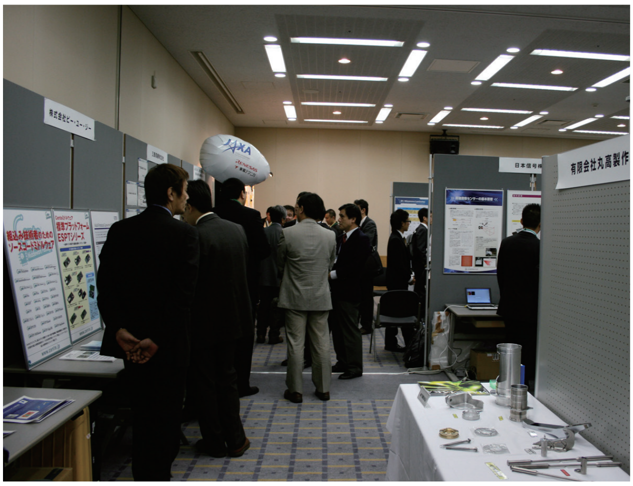

根本　規生（JAXA）


田村　高志（JAXA）

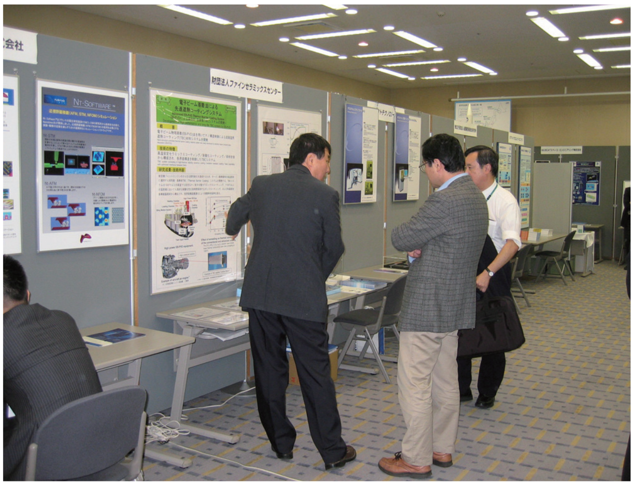
宇宙用部品展示／MEMS & ナノテク展示会

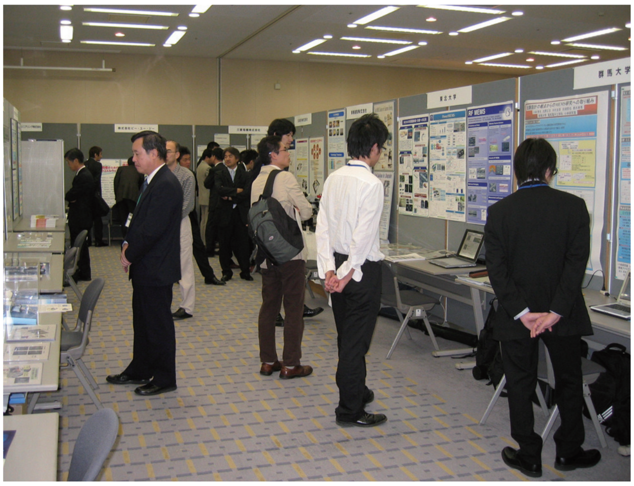


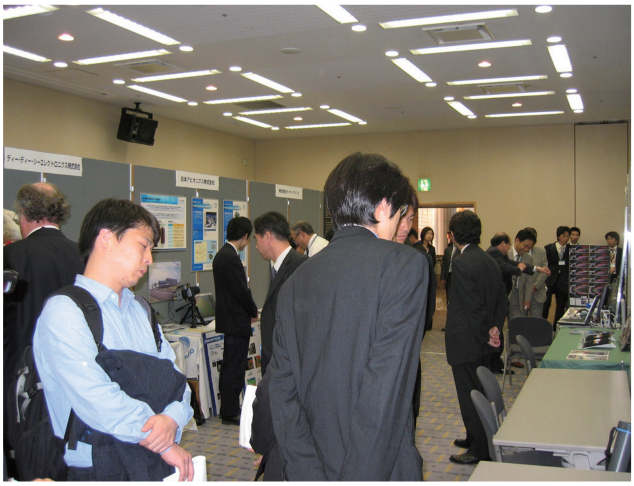


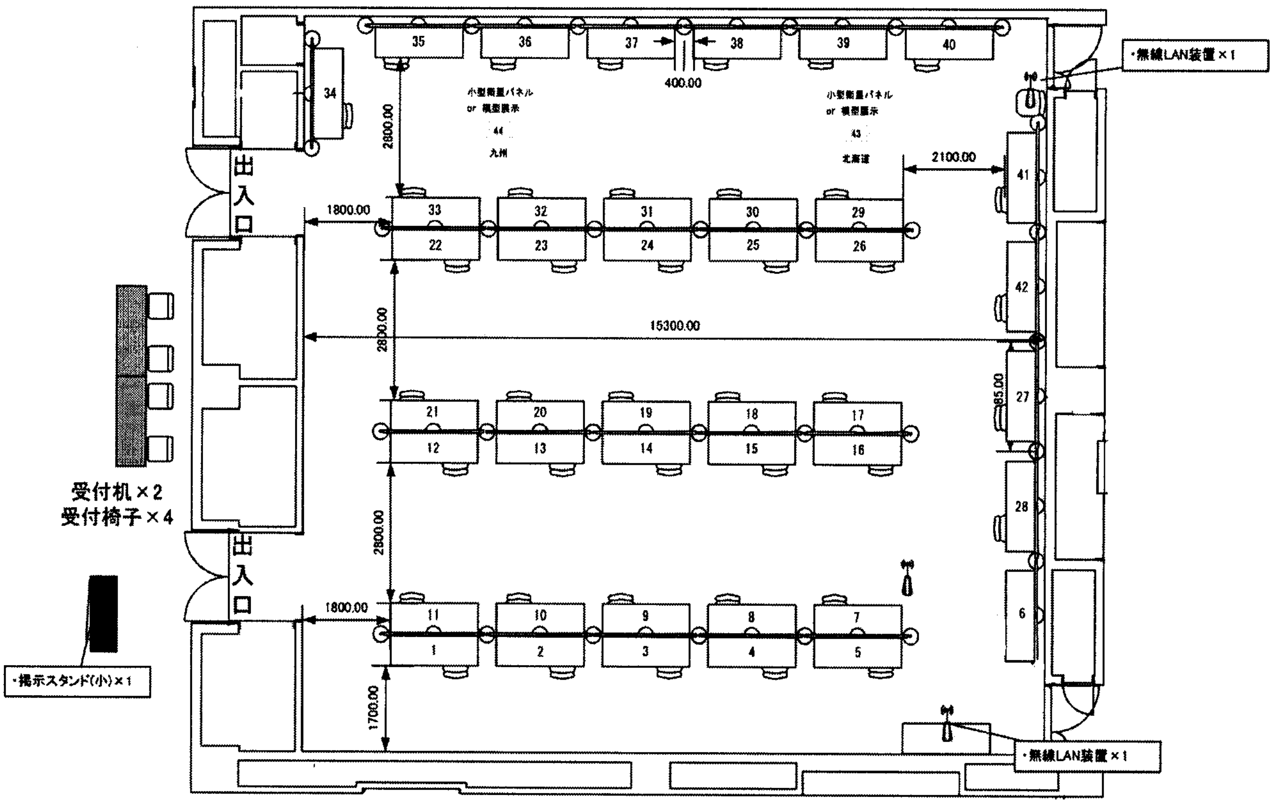


宇宙用部品展示／MEMS & ナノテク展示会









	JAXA 認定部品		MEMS＆ナノテク関連部品		産学官連携部推奨メーカ部品
1	株式会社エイト工業 EIGHTKOUGYOU Co.,Ltd.	16	JAXA　宇宙科学研究本部 高エネルギー天文学研究系　満田・山崎研究室 JAXA　Institute of Space and Astronautical Science Department Of High Energy Astrophysics	29	株式会社エルポート Loyal Port Company Limited
2	株式会社ジェピコ JEPICO Corporation			30	宇宙航空技術利活用研究会（SAT 研） Space Airplane Technology Research
3	株式会社フジ電科 FUJI DENKA INC.	17	日本信号株式会社 THE NIPPON SIGNAL CO.,LTD	31	株式会社山之内製作所 YAMANOUCHI CO., LTD.
4	丸文株式会社 MARUBUN CORPORATION	18	東機通商株式会社 TOKI COMMERCIAL CO., LTD.	32	熱産ヒート株式会社 NESSAN heat CORPORATION
5	JAXA　総合技術研究本部 部品・材料・機構技術グループ　材料・部品関連 JAXA　Institute of Space Technology and Aeronautics Electronic, Mechanical Components and Materials Engineering Group	19	東北大学 TOHOKU UNIVERSITY	33	オービタルエンジニアリング ORBITAL ENGINEERING INC.
		20	群馬大学 Gunma University	34	シキボウ株式会社 Shikibo Ltd
6	株式会社アイティティキャノン ITT Cannon, Ltd.	21	株式会社トキメック TOKIMEC INC.	35	マイクロラボ Micro Laboratory
7	ピーティエム株式会社 PTM Corporation	22	丸紅情報システムズ株式会社 Marubeni Information Systems Co., Ltd.	36	株式会社パウデイック Power Wafers Developement Corporation
8	ディー・ディー・シーエレクトロニクス株式会社 DDC Electronics KK	23	財団法人ファインセラミックスセンター JAPAN FINE CERAMICS CENTER	37	サカセ・アドテック株式会社 SAKASE ADTECH Co.,LTD
9	日本アビオニクス株式会社 NIPPON AVIONICS CO., LTD.	24	ナノクラフトテクノロジーズ株式会社 Nano Craft Technologies Co.	38	株式会社ウェルリサーチ WEL RESEARCH Co., Ltd.
10	株式会社オーケープリント O.K PRINT CORPORATION	25	独立行政法人産業技術総合研究所 ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY	39	宮坂ゴム株式会社 MIYASAKA RUBBER CO., LTD.
11	富士エレクトロニクス株式会社 FUJI ELECTRONICS CO.,LTD.			40	野村ユニソン株式会社 NOMURA UNISON Co.,LTD
12	立山科学工業株式会社 TEYAMA KAGAKU INDUSTRY CO.,LTD.	26	ST マイクロエレクトロニクス ST Microelectronics Co.,Ltd	41	MUSCAT スペース・エンジニアリング株式会社 MUSCAT Space Engeneering Co. Ltd.
13	HIREC 株式会社 High-Reliability Engineering & Components Corporation	27	三菱電機株式会社 Mitsubishi Electric Corporation	42	株式会社ビー・ユー・ジー B.U.G.,Inc.
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宇宙航空研究開発機構特別資料 JAXA－SP－07－017

発 行 日	2008 年 2 月 29 日
編集・発行	宇宙航空研究開発機構
	〒182-8522 東京都調布市深大寺東町 7-44-1
	URL : http://www.jaxa.jp/
印刷・製本	ケーティエス情報(株)

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