

SP-58T

ISSN 0289-260X
UDC 629, 783

**SPECIAL PUBLICATION OF NATIONAL
AEROSPACE LABORATORY**

SP-58T

Small Satellite Symposium 2003

International House of Japan
5-11-16 Roppongi, Minato-ku, Tokyo, Japan
March 12, 2003

June 2003

NATIONAL AEROSPACE LABORATORY

CHOFU, TOKYO, JAPAN

SP-58T

NAL SPECIAL PUBLICATION SP-58T

Small Satellite Symposium 2003

International House of Japan

5-11-16 Roppongi, Minato-ku, Tokyo, Japan

March 12, 2003

Editor in Chief : Atsushi Nakajima

National Aerospace Laboratory of Japan



Small Satellite Symposium 2003



March 12, 2003

International House of Japan
5-11-16 Roppongi, Minato-ku, Tokyo 106-0032, Japan
Tel:+81-3-3470-4611, Fax:+81-3-3479-1738,
<http://www.i-house.or.jp>

Organized by
National Aerospace Laboratory of Japan (NAL)
Small Payload Workshop (SPWS)

まえがき

本報告書は、2003 年 3 月 12 日に国際文化会館で開催された小型衛星シンポジウム「Small Satellite Symposium 2003」の講演論文集である。独立行政法人 航空宇宙技術研究所では、独立行政法人 通信総合研究所、東海大学総合医学研究所等と共同で、平成 12 年度より 3 年間にわたって科学技術振興調整費「高度衛星・通信技術を医療に応用するための研究開発」を実施してきた。本課題は、救急車で搬送される患者の動画像を準天頂衛星経由で救命センターにリアルタイムで送信し、医師の早期診断による病院前救護体制を確立し、救命率向上を目指したプロジェクトの研究開発である。今後、システムの実証実験を行うためには、低価格、早期実現が可能な小型衛星利用が有効であり、そのためのシステム検討や高速データ伝送可能な小型展開アンテナ等の試作を行ってきた。

本シンポジウムは、小型衛星技術、準天頂軌道衛星、遠隔医療等の研究者を招聘(海外から 5 名参加)して開催され、最新の技術情報交換や今後の協調体制を確立していく上でも大変有意義であった。招待講演者、参加者、シンポジウム開催に便宜を図って頂いた航空宇宙技術研究所並びに文科省各位に謝意を表します。

Preface

This issue forms Proceedings of the Small Satellite Symposium 2003, which was held on March 12, 2003 at the International House of Japan, Tokyo. National Aerospace Laboratory of Japan(NAL), cooperated with Communication Research Laboratory of Japan, Tokai University Institute of Medical Sciences and others, has studied the emergency telemedicine project, i.e. patient motion picture transmission in the ambulance via a quasi-zenith satellite to the medical center for the diagnosis by the medical doctor in order to establish the pre-hospital care. Small satellite will be useful for the low-cost and early technology demonstration. Small satellite system, small deployable antenna for the high-bit-rate data transmission and other related technologies have been studied in this project group.

This symposium was supported by the special coordination funds of the Ministry of Education, Culture, Sports, Science and Technology(MEXT) and 5 speakers in the field of small satellite, quasi-zenith orbit satellite and telemedicine were invited from U.S.A, Russia, Australia and Korea. We had a fruitful discussion by exchanging latest information and it will be expected to a future cooperation. We express our thanks to all the speakers, participants, NAL and MEXT for their contributions to this success.

Atsushi Nakajima
Symposium chairman

Contents

Opening Address	v
<p style="text-align: center;">Dr.Atsushi Nakajima (NAL, Japan) Prof.Tomonao Hayashi (CIT, Japan)</p>	
<p>Session1 : Small Payload Workshop(SPWS) Activities Chairman : Prof.I.Nakajima(Tokai Univ.)</p>	
SPWS Activities	1
<p style="text-align: center;">Prof.T.Hayashi (CIT, Japan) Dr.A.Nakajima (NAL, Japan)</p>	
Overview of the USU/AIAA Symposium	7
<p style="text-align: center;">Mr.Y.Yagi (NASDA, Japan)</p>	
UNISEC Activities	15
<p style="text-align: center;">Prof.S.Nakasuka (Univ. of Tokyo, Japan) Prof.S.Kuroki (Soka Univ. , Japan)</p>	
<p>Session 2 : Telemedicine Chairman : Mr.T.Maeda(Hitachi Co.)</p>	
Absolute Coordinate with Quadrant Detector to Track Satellite from Ambulance	27
<p style="text-align: center;">Prof.I.Nakajima (Tokai University, Japan)</p>	
Telemedicine in Russia as Technology and Service	33
<p style="text-align: center;">Dr.Michael Ya. Natenzon (JSC VITANET, Russia)</p>	
Satellite Radio Broadcasting From Inclined Elliptical Orbit	41
<p style="text-align: center;">Dr.Rob Briskman (Sirius Satellite Radio Inc., U.S.A.)</p>	
Motion Picture Transmission System from Ambulance	57
<p style="text-align: center;">Dr.A.Nakajima (NAL, Japan)</p>	
<p>Session 3 : ADEOS-II Piggy-back Satellites Chairman : Prof.S.D.Choi(SaTReCi)</p>	
FedSat Ka band Communications Experiments	73
<p style="text-align: center;">A/Prof.S.Reisenfeld (UTS, Australia)</p>	
Whale Ecology Observation Satellite System	97
<p style="text-align: center;">Prof.T.Hayashi (Chiba Institute of Technology, Japan)</p>	

Oveview and status of Micro Labsat	113
Mr.T.Ohtsubo (NASDA, Japan)	
Mr.N.Takahashi (NASDA, Japan)	
 Session 4:Small Satellite Program Chairman : Dr.A.Nakajima(NAL)	
Light-Satellite for Remote Sensing:Cost Effective Ways for Earth Observation ---	129
Prof. S.D.Choi (SaTReCi, Korea)	
Small Satellite for High-bit-rate Data Communication	145
Mr. H.Okamoto (Astro Research Co., Japan)	
Introduction to MEISAT Mission	159
Dr. Sungdong Park (SaTReCi, Korea)	

Opening address of the symposium chairman

Dr. Atsushi Nakajima
National Aerospace Laboratory of Japan

It is a great pleasure for me to organize the small satellite symposium 2003 held under the sponsorship of National Aerospace Laboratory of Japan and to extend a warm welcome to all our guests. Especially, I would like to express my gratitude and extend a most cordial welcome to the invited speakers who have come all the way to this country to attend this meeting.

The research and developments of small satellites became more actively in the world and more close cooperation will be necessary. It is expected that this symposium will act as a role of exchanging the latest information, deepening the close friendship through the direct discussion with the researchers and promoting the future international cooperation.



In session 1, small satellite activities in the world will be introduced. SPWS(Small Payload Workshop)/UNISEC(University Space Engineering Consortium) are the Japanese non government/non profit organizations. The USU/AIAA annual meeting on small satellite is the largest symposium and the overview of those activities will be presented.

The telemedicine applications using satellite will be expected for future development. In session 2, a motion picture transmission system from the ambulance via a quasi-zenith satellite for the emergency medical care is introduced as an example application. Telemedicine in Russia and the actual applications of the quasi-zenith satellites in the USA will also be presented.

The session 3 is planned for the presentations of the quick operation results of 3 piggy-back microsattellites; FedSat, WEOS and Micro Labsat, which were launched simultaneously by H-IIA launcher last December. For a more advanced missions, a 100 kg-class small satellite will be expected in the near future. Some example missions and satellite designs will be presented in session 4.

I should like to end these words of welcome with an earnest prayer for the great success of this symposium.

Opening address of the SPWS chairman

Prof. Tomonao Hayashi
Chiba Institute of Technology

It is a great pleasure for me to welcome you and to extend an opening address of this symposium.

As you know the idea on the necessity of small satellite activities is steadily penetrating into the space society. How to start for realizing a mission, however, is not yet generally easy. I sincerely hope that at the occasion of this symposium you would obtain valuable clues for developing new challenging fields by means of small satellites.

I would like to have your kind cooperation.



SPWS Activities

Tomonao Hayashi* and Atsushi Nakajima**

* Chiba Institute of Technology

2-17-1 Tsudanuma, Narashino-shi, 275-0016, Chiba, Japan

E-mail: hayat@pf.it-chiba.ac.jp

** National Aerospace Laboratory of Japan

7-44-1 Jindaiji-higashi-machi, Chofu-shi, Tokyo 182-8522, Japan

E-mail: nakajima@nal.go.jp

Abstract

In 1990, the study group targeting on small satellites and their related technology, whose name is Small Payload Workshop(SPWS), was established. The objectives of the SPWS are to review the development of small and microsatellites and their launching system, to study possible missions, to exchange information, to pick up and study the issues to be solved and to contribute to the good and efficient development of the future plan of small and microsatellite utilization. More than 40 organizations are participated in the SPWS now. Three to four meetings and a symposium are held every year and these activities are documented. In 1995, the SPWS has started the study of microsatellites, the weight range under 100kg, by organizing research subgroup, PMSWG(Piggy-back Microsatellite working group). This subgroup focused on the 50kg-class microsatellites which will be launched by H-IIA rocket as piggyback payloads in the near future. The launch opportunities as piggyback payloads will also be opened for various countries. In 1998, the second working group: Telemedicine working group(TMWG) has started its activity. Since then, the TMWG has been studying the worldwide telemedicine information of ITU-D, WHO, WB, APEC, GY, DOD and FCC. Through this activity, NAL and Tokai University Institute of Medical Sciences have acquired a new budget for developing the telemedicine project, i.e. motion picture transmission from ambulance via satellite to the medical center for early diagnosis by medical doctor.

SPWS Activities

Tomonao Hayashi

Chiba Institute of Technology

A.Nakajima

National Aerospace Laboratory of Japan

Small Satellite Symposium 2003

March 12, 2003

SPWS (Small Payload Workshop)

- **Organization**

- Establishment : Jan. 1990, Non Government
- Chairman : Prof.T.Hayashi(Chiba Institute of Technology)
- Members : about 40 Public and Private Organizations
 - National Aerospace Laboratory of Japan(NAL)
 - Communication Research Laboratory of Japan(CRL)
 - National Space Development Agency of Japan(NASDA)
 - Institute of Space and Astronautical Science(ISAS)
 - Universities
 - Private Companies

Study Items of the SPWS

- **Review of Small Satellites and Launchers**
JAS, DEBUT, UoSAT, KITSAT, CONSTRATION,
H-I, -II, -IIA, GALAXY, ARIANE-IV, -V, PEGASUS,
- **Technologies of Small Satellite**
Communication, Attitude Control, Power System, MEMS, COTS,
- **Utilization**
Technology Demonstration, Communication, Earth Observation,
Medical Mission, Biological Mission,
- **Mission Proposals and Requirements**
About 100 Mission Proposals, 3-Axis Attitude Control Technology, High
Bit-rate Data Transmission,
- **Symposium on Small Satellite**
- **Working Groups**
Piggyback Micro-Sat WG(1995), Telemedicine WG(1999)

Piggyback Satellites Examples

Satellite	Development Org.	Mass(kg)	Mission	Launcher/Date	Main Sat.
JAS-1 (Fuji-1)	JARL	50	Amateur Communication	H-I (H15F)	EGS (ASISAI)
MABES (Jindai)	NAL	295	Magnetic Bearing Exp.	1986. 8. 13	
UoSAT3, UoSAT4	Surrey Univ.	43, 45	Comm./Technology Demonstration	ARIANE-IV (F35)	SPOT-2
OSCAR16-19	AMSAT	10- 14	Amateur Communication	1990. 1. 22	
DEBUT (ORIZURU)	NAL, NEC, NISSAN, NIPPI	50	Deployable Mechanism Demonst.	H-I (H21F)	MOS-1b
JAS-1b (FUJI-2)	JARL	50	Amateur Communication	1990. 2. 7	(Momo-1b)
SECS	US Navy	-	Navy Communication	PEGASUS 1990. 4. 5	PEGASAT
BADR-1	Pakistan	52	Communication	CZ-2E 1990. 7. 16	AUSSAT
KITSAT-A	KAIST	50	Comm./Technology Demonstration	ARIANE-IV (F52)	TOPEX/
S80/T	CNES	50	Mobile Communication	1992. 8. 10	POSEIDON
ITAMSAT	INTERFEROMETRICS	10	Amateur Communication	ARIANE-IV (F59)	SPOT-3
EYESAT-A	INTERFEROMETRICS	10	Observation	1993. 9. 25	
POSAT-1	LNETI	48	Comm./Technology Demonstration		
HEALTHSAT	SATELIFE	48	Medical Information from Africa		
KITSAT-B	SATREC	48	Comm./Technology Demonstration		
STELLA	CNES	48	Orbital Measurement		
BREMSAT	Bremen Univ.	63	Scientific Observation/Re-entry	STS-60 (Discovery) 1994. 2. 3	SPACEHAB-2
JAS-2(Fuji-3)	JARL	50	Amateur Communication	H-II (F4)	ADEOS-I
KITSAT-3	SATREC	110	Earth/Environment Observation	PSLV-C2 (India)	IRS-P4
DLR-TUBSAT	DLR	45	Earth Observation	1999. 5. 26	
μ -LabSat	NASDA, NAL, CRL, Tokyo Univ	54	Technology Demonstration	H-IIA (F4)	ADEOS-II
WEOS	Chiba Inst. of Tech.	50	Whale Ecology Observation	2002. 12. 14	
FedSat	CRCSS	58	Communication		

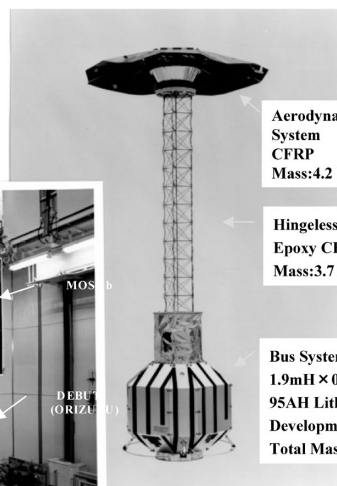
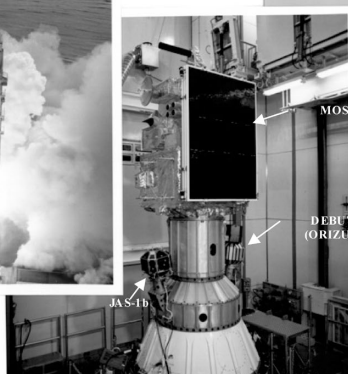
* Nori-deparation from Launcher

Piggyback Microsatellite

National Aerospace Laboratory



Feb. 7, 1990



Aerodynamic Brake System
CFRP
Mass:4.2 kg

Hingeless Mast
Epoxy CFRP
Mass:3.7 kg

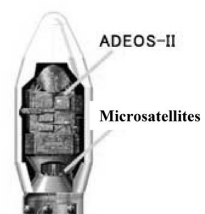
Bus System
1.9mH × 0.44mW
95AH Lithium Battery
Development 1.5 years
Total Mass:50.3 kg

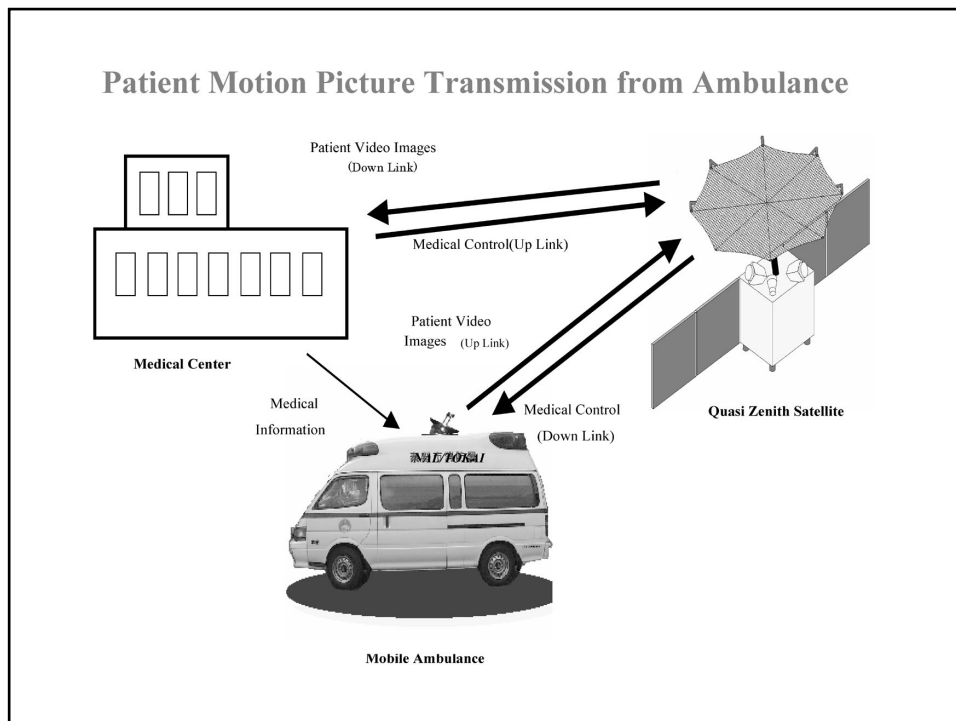
ORIZURU
(1990-013B)

3 Piggyback Microsatellites Launched by H-IIA



Micro LabSat (54kg)
NASDA
WEOS (50kg)
Chiba Institute of Technology
Fed Sat (58kg)
CRCSS (Australia)





Overview of the USU/AIAA Symposium

Small Satellite 2002

- Breakthrough Technologies, The Foundation Of The Future

Y.Yagi, NASDA

Technical Session

I: Existing & Near Term Missions

II: Bold New Missions Using "Breakthrough Technologies" I

III: Bold New Missions Using "Breakthrough Technologies" II

IV: Innovative Mission Operation Concepts

V: Advanced Technologies, Subsystems, Components & Sensors I

VI: 10 Annual AIAA/USU Student Scholarship Competition

VII: Launch Systems & Orbital Maneuvering

VIII: Advanced Technologies, Subsystems, Components & Sensors II

IX: Science & Exploration

X: Lessons Learned

Overview of the USU/AIAA Symposium

NASDA

MICRO SPACE SYSTEMS LABORATORY

YOHEI YAGI

Small Satellite 2002

-Breakthrough Technologies, The Foundation of The Future

Technical Session

I : Existing & Near Term Missions

II : Bold New Missions Using "Breakthrough Technologies" I

III : Bold New Missions Using "Breakthrough Technologies" II

IV : Innovative Mission Operation Concepts

V : Advanced Technologies, Subsystems, Components & Sensors I

VI : 10 Annual AIAA/USU Student Scholarship Competition

VII : Launch Systems & Orbital Maneuvering

VIII : Advanced Technologies, Subsystems, Components & Sensors II

IX : Science & Exploration

X : Lessons Learned

Technical Session I: Existing & Near Term Missions

TU Sat 1: A Novel Communications and Scientific Satellite

- Taylor University [Nano]

MicroVacuum Arc Thruster Design For a CubeSat Class Satellite

- University of Illinois in Urbana and Champaign

Demonstration of Small Satellite Technologies by the BIRD Mission

- Deutsches Zentrum für Luft- und Raumfahrt (DLR)

[Micro: T/D, Sci: Bi-spectral Infrared Detection]

Overview of the NPS Spacecraft Architecture and Technology Demonstration Satellite, NPSAT1D.

- Naval Postgraduate School [Micro]

PCSat and Follow-On Payloads

- US Naval Academy [Pico: Edu, T/D]

Status of the Icarus Student Satellite Mission - A Fully Autonomous Student Built Small Satellite

- University of Michigan [Micro: Tether]

Technical Session II: Bold New Missions Using "Breakthrough Technologies" I

The Inertial Stellar Compass: A New Direction in Spacecraft Attitude Determination

- Draper Laboratory; AFRL [2.5kg, 3.5W]

Next Generation Solar Array Technologies for Small Satellites

- AFRL; Lockheed Martin; AeroAstro [$>100\text{W/kg}$]

FFDEM: Demonstrating Formation Flying with Small Spacecraft

- Surrey Satellite Technology Limited [Micro]

Determining Optimum Modulation for Inter-Satellite Communications Systems

- AeroAstro, Inc.

Preliminary Design of a High Performance Solar Sailing Mission

- AeroAstro, Inc.; Encounter 2001 [3.4g/m^2]

Product Platform Concepts Applied to Small Satellites: A New Multipurpose Radio Concept

- NASA/GSFC; AeroAstro, Inc.

VISTA - A Constellation for Real Time Regional Imaging

- Surrey Satellite Technology Limited, University of Surrey

Technical Session III: Bold New Missions Using "Breakthrough Technologies" II

A Small-Satellite Demonstrator for Generating Artificial Gravity in Space via a Tethered System

- Texas Christian University [Micro]

Design of a Pico Satellite for the Monitoring of a Thin Film Solar Array's Performance

- Lockheed Martin Space Systems Company; Stanford University

A Nanosatellite to Demonstrate GPS Oceanography Reflectometry

- Surrey Satellite Technology Ltd

Design and Implementation of a Sparse Aperture Array Satellite

- MIT

NanoObservatory: A Technology Solution to Enable Earth Imaging for Everyone

- AeroAstro, Inc.

Spaceframe: Modular Spacecraft Building Blocks for Plug and Play Spacecraft

- AeroAstro, Inc.; AFRL

Technical Session IV: Innovative Mission Operation Concepts

Precise Orbit Determination of LEO Formation Flights Using Carrier-Phase Difference and Pseudorange Measurements

- Surrey Space Centre, University of Surrey

AUTOGEN: The Mars 2001 Odyssey and the "Autogen" Process

- Jet Propulsion Laboratory [Automatic command scheduling tool]

A Novel Method for Achieving SAR Imaging with a Pair of Micro-Satellites by Means of a Bi-Static Configuration

- Surrey Satellite Technology Ltd, University of Surrey [Synthetic Aperture Radar]

Epoch Time Assisted Orbit Determination for Near Equatorial Low Earth Orbiting Satellites

- University of Stellenbosch

A Distributed Computing Architecture for Small Satellite and Multi-Spacecraft Missions

- Robotic Systems Laboratory; Santa Clara University

Commanding via the CCSDS Forward CLTU Service

- Applied Physics Laboratory, John Hopkins University

[Consultative Committee for Space Data Systems; Command Link Transfer Unit]

Technical Session V: Advanced Technologies, Subsystems, Components & Sensors I

Electrical Design and Testing of an Uplink Antenna for Nanosatellite Applications

- Virginia Tech [ION-F]

Active Antennas for CubeSat Applications

- University of Hawaii at Manoa

A Low Power Command and Control Module for Small Satellites

- Space Dynamics Laboratory [ION-F]

Continuous Operation of Micro Plasma Thruster "Microwave Engine"

- Hokkaido Institute of Technology [Micro]

NPSAT1 Magnetic Attitude Control System

- Naval Postgraduate School

STPSat-1: A New Approach to DoD Experiment Spaceflight

- AeroAstro, Inc.: Jackson & Tull [Micro: T/D]

Technical Session VI: 10 Annual AIAA/USU Student Scholarship Competition

Attitude Determination for Small Satellites with Modes Pointing Constraints

- Utah State University [ION-F]

Canada's Smallest Satellite: The Canadian Advanced Nanospace experiment (CanX-1)

- University of Toronto

Design Analysis for Solar Sailing from Geosynchronous Transfer Orbit

- Washington University in St. Louis [<50kg]

Practical Results on the Development of a Control Moment Gyro Based Attitude Control System for Agile Small Satellites [Micro]

- University of Surrey

The Electrical System Design, Analysis, Integration, and Construction of the Cal Poly State University CPI CubeSat

- California Polytechnic State University

Two-Axis MOEMS Sun Sensor for Pico Satellites

- Technical University of Denmark

Predictive Thermal Analysis of the Combat Sentinel Satellite

- Utah State University [Nano]

Technical Session VII:Launch Systems & Orbital Maneuvering

Development of a Light-Weight, Reliable, Booster System for SHELS-Launched Payloads

- AFRL; AeroAstro, Inc.

Aerobraking Technology for Earth Orbit Transfers and Microsatellite Aerocapture

- AeroAstro, Inc.; AFRL

A Deployment Strategy for Multiple Secondary Payloads on the MLV-05 Mission

- The Aerospace Corporation

A Monopropellant Multi-Newton Thruster System for Attitude Control of Nanosatellites

- Micro Aerospace Solutions, Inc.

Multiple payload Adapters for Low Cost Space Lift

- AFRL, Kirtland AFB

"Where Do I Start?" Rides to Space for Scientific and Academic Payloads

- Booz Allen Hamilton

Series of Satellite Encounters to Solve Autonomous Formation Assembly Problem

- Surrey Satellite Technology Ltd

Technical Session VIII:Advanced Technologies, Subsystems, Components & Sensors II

Development of a Micro-Newton Thruster for a Drag-Free Control System

- Design_Net Engineering

A Real Time Image Processing Subsystem: GEZGIN

- TUBITAK-BILTEN, Turkey [Micro]

The Ultrasonic Piezo Drive - An Innovative Solution for High Accuracy Positioning

- European Space Agency (ESA/ESTEC); CEDRAT Technologies (France)

Self Deploying, Lightweight, Thin-Film PV Solar Array Structure

- MicroSat Systems Inc.

Technical Session IX: Science & Exploration

Target of Opportunity Multipoint in Situ Measurements with Falcon-SAT-2

- United States Air Force Academy [Nano]

MEMS Technology Demonstration on Traveler I

- University of Southern California [Sub-Orbital Flight]

The Ionospheric Nanosatellite Formation, Exploring Space Weather

- Utah State University [Shuttle Launch]

Design and Test of a Solid State Charged Particle Detector for Cubesat

- Lockheed Martin Missiles & Space Operations

Earthquake Forecast Science Research with a Small Satellite

- Surrey Satellite Technology, Ltd [Micro]

BalloonSat: Missions to the Edge of Space

- Colorado Space Grant Consortium, University of Colorado at Boulder

Technical Session X: Lessons Learned

Kodiak Star - The Mission, the Challenges, the Success - A Look at Lessons Learned from the First Orbital Flight From Alaska

- Kennedy Space Center, NASA [Launch Vehicle]

University Developed Hardware for the Space Shuttle: Strategies for Success

- Jackson & Tull; Utah State University

Results from the Advance Power Technology Experiment on the Starshine 3 Satellite

- Ohio Aerospace Institute/NASA [Micro]

Preparing a COTS Radio for Flight - Lessons Learned from the 3 Corner Satellite Project

- New Mexico State University [Nano: Shuttle Launch]

Lessons Learned of NSPO's Picosatellite Mission: YamSat - 1A, 1B & 1C

- National Space Program Office, Taiwan

AO-40 RUDAK Experiment Controller

- Colorado Satellite Services

Picosats as Payload Carriers

- Montana State University

UNISEC (University Space Engineering Consortium) Activities

Shinichi Nakasuka

Department of Aeronautics and Astronautics, University of Tokyo
7-3-1, Hongo, Bunkyo-ku, Tokyo 113-8656, JAPAN

Seiji Kuroki

Faculty of Engineering, Soka University
Hachioji, Tokyo, 192-8577, Japan

UNISEC Home Page: <http://www.unisec.jp>

This paper reviews the current status of space engineering education in Japan especially centered on micro satellites. Hands-on training using micro satellites provide unique opportunity of space education to university level students, by giving them a chance to experience the whole space project cycle from mission creation, satellite design, fabrication, test, launch, operation through analysis of the results. Project management and team working are other important skills that can be trained in these projects.

The key features of micro satellites contributing to this benefit include 1) low cost, which allows one laboratory in university to carry out a project, 2) short development period such as one or two year, which enables students to obtain the results of their projects before they graduate, and 3) small size and weight, which enables fabrication and test within usually very narrow university laboratory areas. The important consideration is that the satellite made by the students should be launched, or even if that is impossible, should be tested in nearly the same environment as the actually launched case. This is important because with this experiments, the students can get feedbacks from the real world, sometimes in the form of very hard results, which will be valuable materials towards the next step. And, of course, the feeling "Our satellite will be launched" would tremendously contribute to their motivation.

Considering these benefits of micro satellites, many universities in the world have been devoted to their own micro satellite projects since late 1980s. Japan was a little behind US and Europe in this field in early 1990s, but now is gradually catching up them.

The first activity, "Satellite Design Contest" was initiated in 1993 to trigger the movement towards the hand made satellite as well as broaden the students who are interested in space technology. It has been very successful in the sense that many universities could acquire skills and knowledge of satellite design, and that the piggyback launch opportunity of H-IIA has been approved, thanks to the efforts of many people related to the contest. USSS (University Space Systems Symposium) started in 1998 to promote university students' joint projects between US and Japan. It has produced many interesting satellite projects such as CanSat, CubeSat and Quest, and has contributed a lot to stepping up from paper work level to real hand-made projects. CubeSats are currently waiting for actual orbital launch in 2003.

In 2001, "University Satellite Consortium" was established with the objective to make a university student and staff community of these micro satellite related activities in Japan, which was integrated with hand-made rocket group into larger community named "UNISEC (University Space Engineering Consortium)". This consortium aims for many activities including facilitating information and skills exchange and collaborations between member universities, helping students to use ground test facilities of national laboratories, consulting them on political or law related matters, coordinating joint development of equipments or

projects, and bridging between these university activities and the needs or interests of the people in general. This kind of outreach activity is essential because how to create missions of micro satellites should be pursued in order for this field to grow larger than a merely educational enterprise. The final objectives of the consortium is to make a huge community of the users, mission creators, investors and manufactures (university students) of micro satellites and rockets, and provide a unique contribution to the activation of the space development.



UNISEC

University Space Engineering Consortium

UNISEC Activities

Shinichi Nakasuka

University of Tokyo

Seiji Kuroki

Soka University

Significance of University Micro/Nano/PicoSat Projects

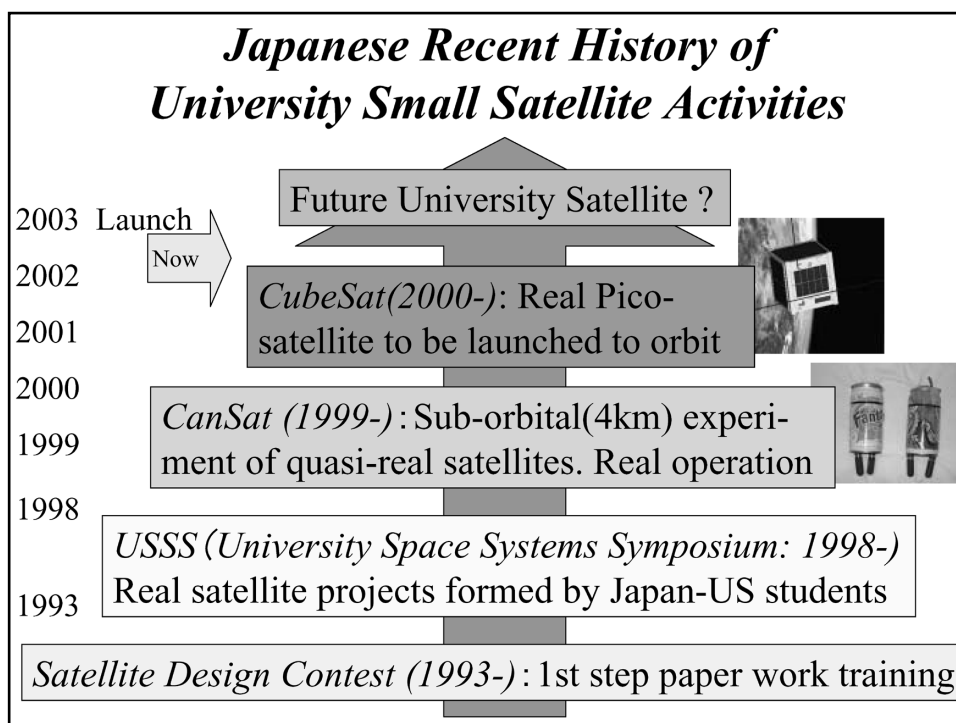
- Providing Excellent Material for Space Engineering Education
- Opening New Ways of Space Development
- Bridging between Space Community and General Public/Local Community

University Contribution to Space Development Using Small Satellites

- Hand-made small-sats: *Quick and low cost* test bench for advanced technologies or missions
- Providing *large number of “Trial-and-Errors”* for technology seeds generation/exploration
- Education and training of human resource
- *Constraints* open new ways of development
 - Students \Rightarrow Less than 1 \sim 2 years development cycle
 - Stringent budget \Rightarrow COTS utilization
 - Weight/volume/power limit \Rightarrow novel configuration

Small Satellites for Space Education

- *Practical Training of Whole Cycle of Space Development*
 - Mission conceptualization, satellite design, fabrication, ground test, modification, launch and operation
 - Know what is important and what is not.
- *Importance for Engineering Education*
 - Synthesis (not Analysis) of an effective system
 - Feedbacks from the real world to evaluate design, test, etc.
- *Education of Project Management*
 - Four Managements: Time, human resources, cost and risk
 - Team work, conflict resolution
 - Effective discussion, documentation
 - International cooperation, negotiation, mutual understanding



University Space Engineering Consortium

- Mission
 - Support university satellite and rocket projects for technology development, space education and international cooperation
- Tasks
 - Searching for fund and distributing it
 - Arrange students' usage of agency/companies test facility
 - Arrange technological support from agency/companies
 - Arrange information exchange, workshop among universities
 - Help multi-university joint development of equipment, joint purchase of parts/equipment or other collaborative activities
 - Tackle together political problems such as frequency allocation, export/import of satellites/subsystems, etc.
- Authorized as NPO in 2003.2 <http://www.unisec.jp>

Participating Universities/Colleges

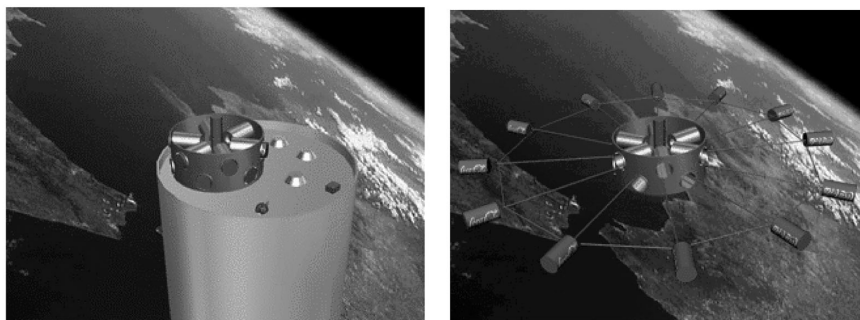
Satellite Groups:

University of Tokyo Tokyo Institute of Technology
Nihon University Soka University
Kyushu University Tohoku University
Hokkaido Institute of Technology
Tokyo Metropolitan College of Aeronautical Engineering
Kyushu Tokai University
University for Electro-Communications

Rocket Groups:

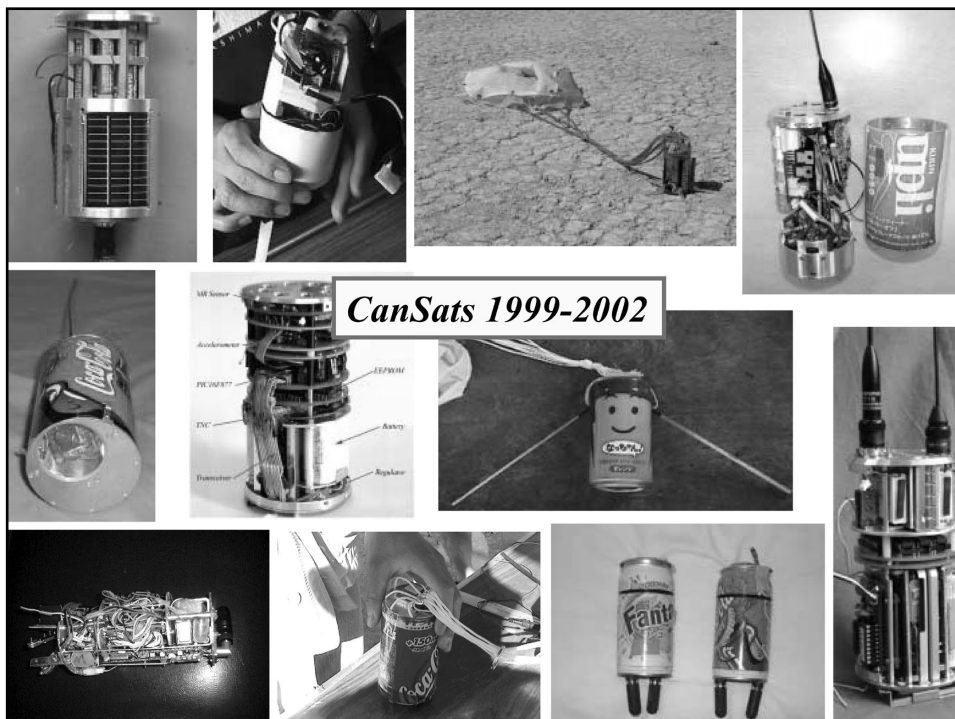
Hokkaido University Hokkaido Institute of Technology
Osaka Prefectural University Aoyama-Gakuin University
Muroran Institute of Technology Tokai University
Tokyo Metropolitan Institute of Technology
Tokyo Metropolitan College of Aeronautical Engineering

Initial Concept of CanSats Program (Proposed in USSS 1998 by Prof. Twiggs)



(<http://www.ae.utexas.edu/~cansat/>)

-

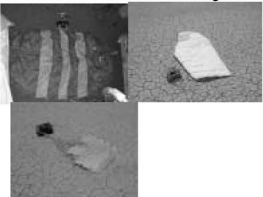










Come-Back Competition 2002

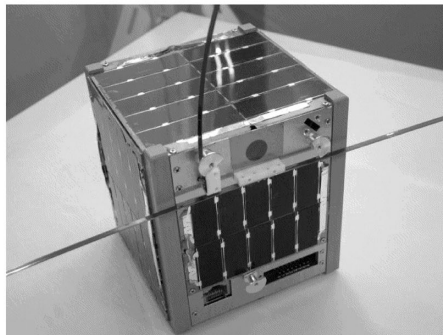
Participating Universities 2002

Univ. of Tokyo 	Kyushu Univ. 	Nihon Univ. 
Tohoku Univ. 	Tokyo Institute of Technology 	Stanford Univ. <div style="border: 1px solid black; padding: 5px; text-align: center;">ROVER</div>





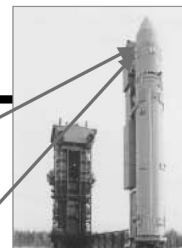
CubeSat Projects



Currently being developed by

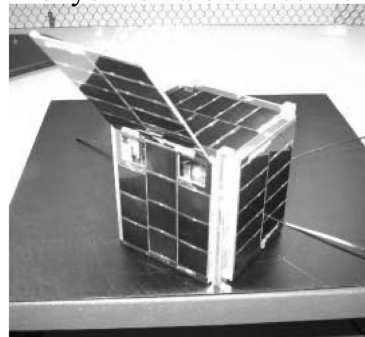
- Nihon University
- Soka University
- etc.

University of
Tokyo



To be launched in June 2003

Tokyo Institute of Technology



Rocket Group Activities

- Hybrid rocket propulsion/launch experiment
- Fly-back type rocket upper stage (parachute or winged)
- International joint launch in Alaska



Taiki-cho
launch
experiment
held
annually

Issues to be Solved to Further Facilitate the Movement

- *Reliability improvement without additional cost*
 - Technology “heritage” and strategic development
- *Frequency permission*
 - International joint endeavor for “educational frequency”
- *Launch opportunity*
 - Clustered launch arrangement or Japanese piggyback
- *Funding*
 - Not only from government but also from general public and private companies
- *Debris Mitigation*
 - Change ballistic parameters at the end of life, etc.

Absolute coordinate with Quadrant detector to track satellite from ambulance

Isao Nakajima, M.D., Ph.D.
Tokai University Institute of Medical Sciences

ABSTRACT

Tokai University has been conducting research on ambulances and related onboard systems for transmitting video images from vehicles in motion via the quasi-zenith satellite, which are scheduled to be launched by the Communications Research Laboratory (CRL) and the NASDA. This paper describes a newly-developed high-precision satellite tracking system, which we have developed for use with this system. The core of this tracking system comprises a few mutually complementing independent signal processing subsystems. Within this system, the absolute coordinates of the satellite are estimated by a quadrant detector(QD), while its relative coordinates are estimated by a GPS-based continuous kinematic positioning technique and calculations of six orbit elements. As we intend to use Ka-band transponder and to use narrow beam antenna of the vehicle. So here, we would like to discuss the effect of absolute coordinate with the quadrant detector to track satellite at urban area.



Fig. 1 GPS antenna for Continuous kinematic positioning

OBJECTIVE

We have designed and made a prototype of a satellite tracking system to be installed in emergency ambulances for tracking a quasi-zenith satellite.

SYSTEM

Target satellite

A geostationary satellite (GEO) may be used in areas near the equator and flat areas with few obstructions. For Japan, however, which is located 30 to 45(north latitude, a quasi-zenith satellite is most suitable for data transmission (i.e., uplinks to a satellite) from ambulances operating in urban areas, because such a satellite can avoid shadowing (blocking) and maintain a high angle of elevation for a long time. The quasi-zenith satellite referred to here will be a Quasi-Zenith Satellite (a 45-degree inclined synchronous orbiter).

Tracking mechanics

We have mounted on the roof of an ambulance two tracking systems that can operate in the 25-90 degree angle of elevation range and up to a continuous 660-degree azimuth range to track either a geostationary satellite or HEO. The drive system features a compact, simple design, and mechanically controls a Cassegrain antenna 50 cm in diameter (weight: kg; target radio bands: X, Ku and Ka; feeder unit: optional). Two DC motor systems for azimuth and elevation control are installed, and the reduction gears have a harmonic drive mechanism with non-backlash gears aligned on a single input/output line. A transmission belt links the harmonic drive and turntable.

Track systems

First, six parameters of the satellite's orbit are entered into an on-board computer, then the position gap detected by sensors is diminished step by step. Specifically, the on-board computer (running Linux) calculates the displacement of estimated satellite position from the true position based on data provided by input systems consisting of GPS sensors, an inclinometer, and a quadrant detector. Then, the computer generates an output signal to control the drive motors (of the azimuth and elevation control systems). The tracking method (with 3-5 operations per second) has a closed loop of sensors and motors. It first corrects 75% of the total positioning error, then performs fine-tuning based on feedback from the sensors. The following A-C sensors provide the tracking system with information about azimuth (AZ) and elevation (EL) control.

A. GPS interference positioning (Continuous kinematic positioning)

GPS interference positioning and continuous kinematic positioning are technologies used to receive signals simultaneously sent from GPS satellites at two sites, and to determine the relative coordinates of one receiving point against the other based on the measured phase of the carrier wave. We obtain directional data in 3D coordinates from three GPS receivers. The GPS interference positioning provides higher accuracy than the popular single positioning method or so-called translocation method. Such positioning can obtain relative coordinates approximating the absolute coordinates of the target satellite (particularly in the X-Y plane).

Features:

1. Receives carrier waves sent from GPS satellites with three antennas, then calculates phase shift.

2. Directional accuracy: one degree
3. Start-up time: three minutes
4. High-speed rotation: 25 degrees/sec
5. A proprietary three-antenna system that is less vulnerable to pitching or rolling
6. Prepares for instantaneous GPS signal interruptions by installing a gyro-compass as backup.

B. Quadrant detector

Data transmission from an ambulance to the satellite is the major part of data flow in the current system. However, concurrently with transmission four spatially separated receiving circuits (all located the same distance from the center of the Cassegrain antenna feeding unit) concurrently catch weak pilot beacons sent from the satellite. Four DSPs along the time axis integrate these received signals to calculate four magnitudes of electric power. The differences between these four values of arriving power are determined based on the beacon angle and four spatial coordinates (Fig.2-4). The output given to the drive system for fine-tuning of the azimuth and angles of elevation can then be calculated with reference to a conversion table covering each antenna pattern. For use under multipath conditions (e.g., with Nakagami-Rice fading, Loo fading), the quadrant detector works better than so-called monopulse antennas because it has an independent array structure (i.e., independent heterodyne receiver). The monopulse antenna is widely used in a number of radar tracking systems to indicate the direction of arriving signals by a simple comparison of voltage amplitudes, and by integrating the voltage values of the same phase with those of the reverse phase. The quadrant detector provides the absolute coordinates of the satellite.

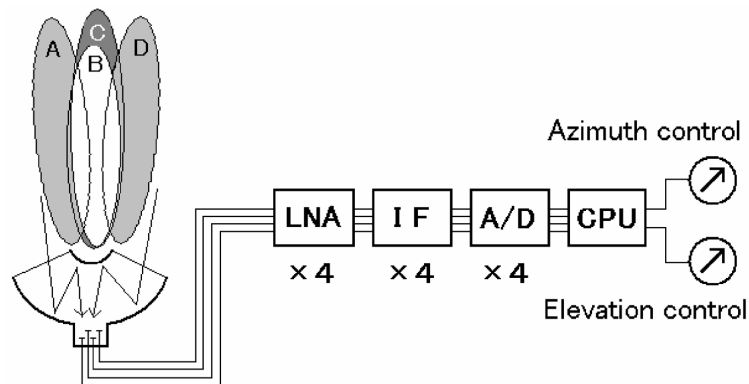


Fig. 2 System concept of Quadrant Detector

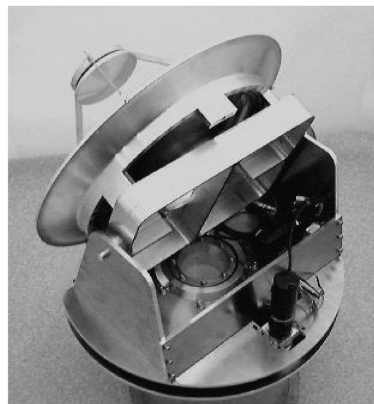


Fig. 3 On board antenna(40cm diameter Ku- Ka band)

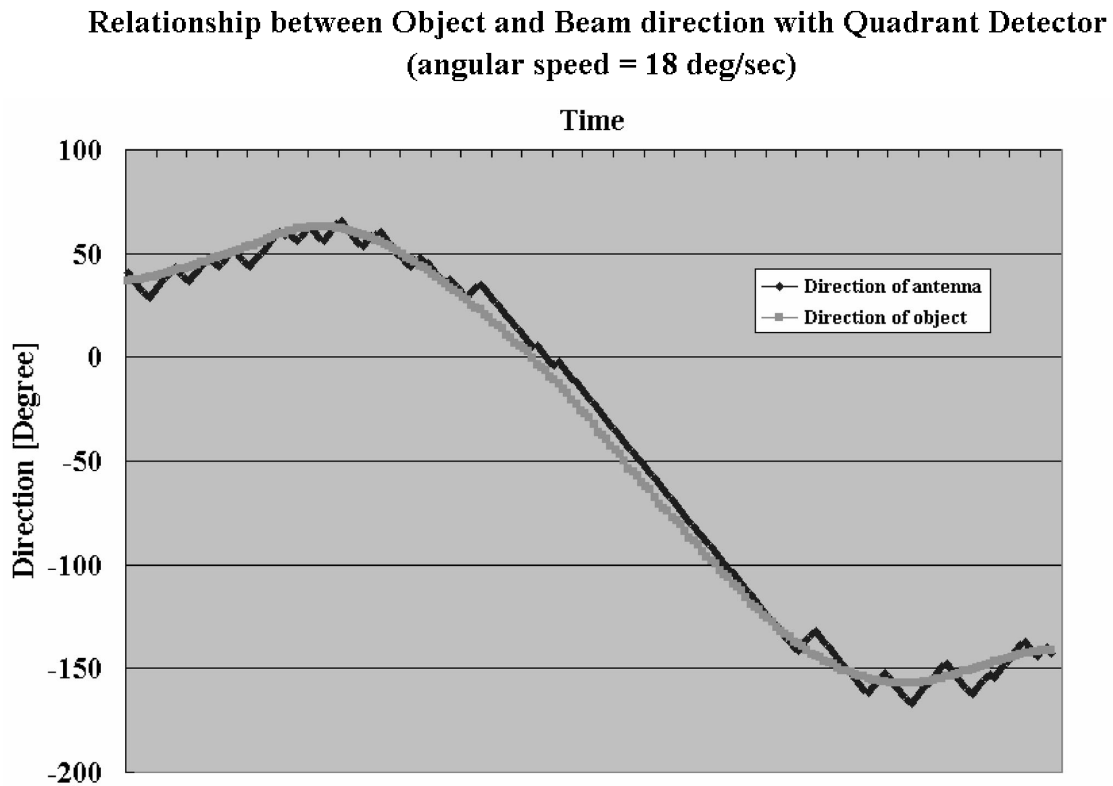


Fig. 4 Test results of the tracking accuracy of the Quadrant Detector

DISCUSSION

Tracking ability of the quadrant detector

Tracking a satellite requires knowledge of its coordinates. If the satellite is visible, we can obtain absolute coordinates. Relative coordinates can be obtained by calculating the position of the satellite based on the six orbit elements, and the direction of the running vehicle can be obtained by any means. This can be summarized as follows:

- Relative coordinates

Calculated from the six orbit elements and the direction of the vehicle. The calculation amounts to a rough approximation.

Tools and method: Optical-gyro, Magnetic sensor, D-GPS

- Absolute coordinates

Receive signals from the satellite and measure the angle of arriving signals (direct line of sight of satellite). Tools and method: Quadrant detector, Step-tracking, Mono-pulse method, Higher-order mode method.

A mono-pulse antenna, which uses the sum and difference in high-frequency signal level, is recommended for signals that show no feeding. In contrast, for moving objects that causes signal feeding, a diversity antenna (or independent two-array antennas) are highly effective. Combined use of two antennas with high-frequency signal levels. The receiving power is expressed by the following equation for the case wherein an ambulance moving underneath a plurality of evenly spaced electric wires (slit with an interval D) receives incoming waves at an angle θ :

$$I(\theta) = I(0) \left| \frac{\sin\left(\frac{\pi}{\lambda} D \sin \theta\right)}{\frac{\pi}{\lambda} D \sin \theta} \right|^2$$

Microwaves that have passed evenly spaced barriers are selectively received one by one, with results similar to that obtained by FFT expansion. Thus, if a mono-pulse antenna combining microwaves in the state of high frequencies (two or more trigonometric functions are combined) is used to receive feeding signals, the separation system is rendered worthless. Gaussian noise, whose expectation value is zero, can be removed by providing and integrating four independent signals along the time axis.

The quadrant detector outputs the coordinates of arriving signals by comparing the average receiving powers in the four independent systems. The resulting tracking ability was high enough for practical use,, which shows the quadrant detector's performance, obtained as the vehicle turned a 90-degree corner in five seconds.

ACKNOWLEDGMENTS

This study was performed through Special Coordination Funds of the Ministry of Education, Culture, Sports, Science and Technology, the Japanese Government. We would like to offer our thanks to Mr. Masuhisa Ta at Tasada Works Inc. for his many useful suggestions.

REFERENCES

01. I. Nakajima, H. Juzoji."Toshikankyo ni okeru jushindenryoku no sokutei (Receiving signal strength from COMETS ICE beacon)." Proc. Symposium of COMETS 2000:pp127-133, 2000 (in Japanese)
02. C. Ohuchi, M. Shimada, et. al. "Development of the COMETS Satellite System." Rev. of the CRL Vol. 43, No.1:pp25-34,1997 (in Japanese)
03. W. H. Delashmit."Satellite Intercept Targeting DSP Algorithm Design and Evaluation." IEEE Trans. AES Vol. 29, No. 3:pp726-739, 1993.
04. A. D. Seifer. "Monopulse-Radar Angle Tracking in Noise or Noise Jamming." IEEE Trans. AES Vol. 28, No. 3:pp622-638, 1992.
05. Y. Arimoto."Hosoku Tsuibi ni okeru 2kyokukan sougosayou ." Hikarieiseitsusin:pp74-75,1995 (ATR technology published by Ohmsha, in Japanese).

TELEMEDICINE IN RUSSIA AS TECHNOLOGY AND SERVICE

Natenzon M.Y., Tarnopolsky V.I.

“TANA” Companies Group

“VITANET” public company

Moscow, Starovagankovsky per., 15, office 14

Since antiquity, providing medical services has been one of the traditional integral parts of economy. Nevertheless, the market of medical services has been always related to the intellectual sphere and therefore has been always receptive to new technologies. Today the market of medical services demonstrates high-growth potential and typical features of the new economy: sharing and direct use of professionals' knowledge and experience through the use of telecommunications technologies.

What is Telemedicine?

New technologies rapidly developing at the end of the XX century – computer and telecommunications technologies – have found wide application in different spheres of human life such as medicine and healthcare. One of such applications, that use digital data processing and digital methods for storing medical diagnostic data and special methods for secure data transfer through communication links, was called **telemedicine**.

But only since 1995, it has become possible to introduce telemedicine into medical practice due to joint efforts of governments of some Northern countries, Norway in particular, and oil and gas transnational companies, which allows doctors to provide medical services to people in remote or difficult-to-access regions, for example to oil workers at offshore oil rigs.

On the other hand, in the most complicated cases across the world, telemedicine is the most efficient means of providing medical care & consulting, independently of the physical location of people who need care.

*Thus, **telemedicine** is a set of organizational, technological and commercial measures to provide functioning of the consultative-diagnostic system when any patient or doctor can receive a distant consultation from a specialist through the use of specialized equipment and telecommunications.*

Some facts from the history and brief overview of telemedicine in Russia

The pioneers in using telemedicine technologies in the USSR were aviation and space doctors who handled and analysed telemetric information about the health state of pilots, then astronauts, during their flights.

It should be noted that telemedicine technologies were used in the USSR to liquidate disaster consequences. The first experience of using new technologies (in fact it was international experience) was during the Spitak earthquake in Armenia. Later telemedicine was used during the fire on a train suffered from a blow on gas pipeline near Ufa.

Telemedicine in Russia has been developing in several directions concurrently: at the governmental level and in the private sector, in regions and at the federal level.

Until recently, almost in each Ministry there was a committee on telemedicine. Today in order to better coordinate the work at the State level, a Coordinating Committee on Telemedicine was created, headed by L. Reiman (the RF Minister for Communications and Information) and Y. Shevchenko (the RF Minister for Health).

Russia is one of few countries across the globe (I dare say Russia is the only one) that has the State “Concept of development of telemedicine technologies in the RF” adopted. The concept was adopted by the RF Ministry of Health in 2001.

The adaptation of the State “Electronic Russia” program by the RF government in 2001 was a real breakthrough of telemedicine. According to this program, in 2003 there in Russia will

be created some areas where different types of telemedicine equipment and methods for providing functioning of telemedicine systems will be tried. These areas will be created in the Chuvash Republic, Belgorod and Lipetsk regions, at some nuclear power plants and disaster centres.

If successful, it is planned to launch a nationwide telemedicine network in 2004. All these projects will be financed by the State, regional governments and insurance companies on an equal footing.

All telemedicine projects can be divided into several categories. Mainly, in Russia there have been carried out consultations between doctors from large regional in-patient clinics and leading specialists from the State medical centres located in Moscow. In parallel, leading specialists carry out master-classes and training for their colleagues from regions.

Recently, there appeared new telemedicine projects based on using mobile systems and equipment.

A revolutionary new application of telemedicine in Russia has been using telemedicine equipment for creating a network of General Practitioners' Offices.

Creators of telemedicine systems in Russia have been facing a number of legal problems. Thus, in order to overcome these difficulties, the State Duma created a Working Group on Telemedicine to consolidate the experience gained and to prepare a law on telemedicine.

Currently Russia has a considerable number of telemedicine projects under way, each implemented to some extent. These are projects by such RF medical centres as the Medicine Centre of Affairs of the RF President, the Research Centre for Cardiovascular surgery named after Bakhuleva, Moscow Scientific Research Institute of Paediatrics and Child Surgery, Moscow Medical Academy's National Research Centre of Surgery, Research Neurosurgery Centre named after Burdenko, State Medicine Centre.

A number of telemedicine networks are currently being built at different levels: departmental (i.e., the most developed project is a project for the RF Ministry of Transport and Communications), corporate (i.e., the Russian UKOS Oil Company) and specialized (i.e., within the framework of the program to fight tuberculosis)

Telemedicine technologies are being actively introduced into the medicine practice in some regions across Russia.

What facilities can Telemedicine offer?

The market of medical services may be divided into three segments according to potential demand:

- Emergent medical care delivered to the patient (injured) in dangerous to life or health situations that must be dealt with immediately; personal medical monitoring for the health condition of the elderly or disables people;
- Primary Health Care aimed at satisfying primary medical needs of people;
- Specialized and highly specialized high-quality consultative-diagnostic and health management care including surgical medical aid.

The listed-above segments greatly benefit from using the most important telemedicine technologies, namely:

«*Clinical Telemedicine*» lets doctors receive on-the-fly consultative-diagnostic help from the leading Medical Centers of Russia and other countries in order to provide medical care to patients wherever they live.

«*Personal*» and «*Home*» telemedicine utilize modern means of establishing individual communications such as mobile and/or connecting to the Internet in order to obtain specific personified recommendations: a qualified analysis of information about the patient's health condition (electrocardiogram, pulsometer data, etc.) can be sent from the Consultant to the Doctor in charge of the case through the use of telemedicine technologies.

«*Medical Depository*» uses modern means of communications in order to store the patient's medical data (e-medical history, including medical images) in a separate file, which both the patient and his doctor can access from any geographic point.

Where and how can Telemedicine help?

1. **Improving the quality of medical care; making high-quality medical care a uniform standard nationwide.** The use of telemedicine technologies helps solve such socially sound problems of the Health Care system as providing affordable, uniform standard medical services from any medical center independently of its physical and hierarchical location. This can be achieved by giving doctors and patients the possibility to receive professional consultations on a particular disease from leading specialists in a particular field.
2. **Providing medical services to people staying or living in remote or difficult-to-access regions.** In such regions medicine centres have small staff (one or two GPs or medical attendants) who call emergency in all complicated cases or ask to take the patient to a major medicine centre if they are unable to provide the appropriate care. Equipping such centres with special telemedicine-aided diagnostic facilities will enable local medical staff to receive telemedicine consultations from specialists without the need to transport patients to hospital.
3. **Providing medical care in cases of emergencies.** As a rule, a lot of specialists, medical specialists inclusive, are sent to the places of natural cataclysms, technogenic catastrophes, etc. where their help is indispensable. But in the most complicated cases (that happen very often), highly specialized help is needed while the specialist who can deliver the appropriate help can be hundreds kilometres away from the place of tragedy.
4. **Consultations provided from the leading medicine centres across the world.** The typical feature of the Former Republics of the USSR was concentration of leading medical professionals in Moscow and other capitals of the Union Republics in spite of the great total number of medical institutions scattered across the country. As a consequence, patients from different regions were heading to the capitals to receive high-quality medical care. After the USSR disintegrated and the cost of long distance trips raised, most people found themselves incapable of getting medical care from the leading specialists. Telemedicine can successfully solve this problem. Any patient can receive the necessary consultation from the best specialist in the field from any diagnostic centre across the globe (no matter where exactly the doctor works or lives), without the need to go to another hospital. In special cases the patient can be transported to a particular medical institution where highly specialized care can be provided according to a thoroughly prepared plan.
5. **Getting medical treatment abroad.** Certain groups of population can afford quality medical treatment. But the cost of such treatment abroad is much higher than in their native country. Therefore the selection of a medical institution abroad done on the basis of the results of a telemedicine consultation can be more reasonable, which can reduce the amount and total cost of treatment.
6. **Providing postoperative monitoring and support to the patients.** During the period of recovery after serious operations such as neurosurgical, cardiosurgical, etc., patients need continuous or periodical monitoring and support from the doctor who operated upon the patient. As a rule, such operations are performed in large medicine centres located in large cities, whereto non-resident patients may find it difficult to come – the time and cost of trips can be considerable. The problem can be solved through the use of telemedicine.
7. **Continuous training and re-training of medical staff.** New technologies reshaping our world and fast progress necessitate more training, making the task of distant training

– that is training in places where medical staff work – really crucial. Part of this problem is giving the specialists access to the most up-to-date medical information and news. Besides, doctors receiving consultations from highly qualified specialists gain experience and practical skills indispensable in their work.

8. **Creation of a database to store medical information.** To provide affordable and uniform-standard medical care, it is necessary to intelligently collect and store medical and medicine-related information in a database so that doctors and Health Officials could access it whenever needed. This will guarantee that all persons responsible for providing high-quality health care use actual data and are well informed about the current public health state (i.e., sickness rate across regions, the case history of a particular patient, etc.). Clever usage of distributed DBMSs in combination with telemedicine can satisfy many vital needs.

How are telemedicine consultations carried out?

In the context of «Clinical Telemedicine» the purpose of carrying out telemedicine consultations is four-fold:

- Verification of the results of a separate diagnostic examination;
- Diagnosis verification;
- Verification of medical tactics;
- Determining the medical grounds for getting medical treatment in Russia or abroad.

It should be noted that it is possible to provide both *off-line* and *on-line* telemedicine consultations through the use of special technologies.

The *off-line* mode of carrying out a telemedicine consultation suggests that all the necessary medical data is provided prior to consultation so that the Consultant can analyse it off-line, prepare a medical certificate or get prepared for an on-line consultation. In most cases it is enough to carry out an off-line telemedicine consultation.

In complicated cases when audio/visual contact between the Consultant and patient is needed, it is required to carry out *on-line* consultations. During an on-line consultation both parties can discuss the problem in real time, can see each other and the necessary medical information displayed on their screens.

The kind of telemedicine equipment needed for carrying out telemedicine consultations greatly depends on the expected number of telemedicine consultations. However, from the functional viewpoint telemedicine centres must be equipped with special facilities to process such data as results of X-ray diagnostics (i.e., X-raying, tomography, ultrasonic examination, etc.), cytological and histological examination, endomorphism and functional diagnostics.

Small telemedicine offices can be equipped with one workstation capable of performing the functions of a telemedicine terminal, a workstation for preparing the necessary medical documents and a server.

Telemedicine centres located in large medical institutions are usually equipped with:

- Telemedicine terminal;
- Videoconference-terminal (a station for carrying out group videoconferences);
- Specialized stations for teleconsulting;
- DB and Communications Server;
- Auxiliary equipment.

Examples of such telemedicine workshop's configuration and possible arrangement of equipment in a room are shown in Fig. 1 and 2.

What is Telemedicine in Russia?

Active interaction between those involved in the process of developing telemedicine in Russia resulted in a clearly defined business model for the market of telemedicine services, the participants of which are as follows:

- Specialized medicine centres acting as providers of medical consultative-diagnostic services;
- Preventive health care centres of different sizes and on different levels, offices and networks of the GP offices, insurance companies and private persons that buy medical services;
- Providers of telemedicine services – operators of medical air responsible for providing telemedicine services.

The key problem in developing telemedicine in Russia is a problem of expanding customer database, which requires building more telemedicine centres and offices across all regions.

What are the economic grounds for telemedicine?

It is well known that in the tsar's Russia, then in the USSR, now again in Russia, patients go to the capital to be treated by a Moscow professor. It is not just a matter of tradition, it is a real life situation: it is perfectly possible to equip any hospital in any remote area with the most up-to-date facilities but equipment is nothing without a good specialist.

According to statistics, late in the 80s Moscow accommodated up to 12-15 million patients seeking treatment from leading specialists annually. Russia's political and economic crises followed by rising travelling costs lowered this figure to 1 million patients per year. As a result, almost 10 million patients find it impossible to receive affordable high quality medical care. Followed-up social and financial losses cannot be estimated precisely, but a rough estimate is many billions of rubles. These losses can be caused by different factors such as mal treatment resulting in total disability or the low-load of federal medicine centres that is inefficient usage of medicine resources.

Telemedicine technologies let us considerably reduce the cost of medical care by providing high quality health care services quickly that is reducing time, by reducing transport expenses, by shortening the recovery periods that is reducing social security disability insurance benefits.

Taking into account the large sizes of Russia, the total cost of a patient's coming/travelling to central clinics, his/her examination and followed treatment is about \$700-1000 (US). This cost does not include losses related to the wasted working days, sick payments, second visit to the doctor, etc. The average cost of telemedicine consultation is about \$100-150 (US). The mentioned about figures clearly show the economic effectiveness of telemedicine technologies as regards both the consumer of medical services and local budgets. As regards the annual financing of federal social programs, the cost of equipping telemedicine consultative-diagnostic centres in regions is less than the amount of money currently allocated for such programs.

The statistics across the world shows 25% annual growth in the market of telemedicine services. Only in the USA in 1997 that was the first year of wide application of telemedicine technologies by insurance companies, the amount of telemedicine consultations totalled 6 billion USD. According to international experts, the volume of the market of telemedicine services targeting only the elderly people across the wealthy countries with strong economy will amount 1 trillion USD by 2025. The capacity of the Russian telemedicine market can grow up to 0.65-1 billion UDS by 2007.

What is the specialization of "TANA" and "VITANET"?

The "TANA" companies group is the developer and provider of telemedicine equipment and appropriate software, as well as an independent provider of telemedicine services. Besides, the "TANA" companies group actively participates in the formation of the Russian and international markets of telemedicine services, targeting such important market segments as:

- Providing telemedicine consultative-diagnostic services in complicated medical cases;

- Creating networks of Family Doctor offices in large cities, equipping the offices with the necessary facilities;
- Improving the quality of medical care provided to people staying/living in remote or difficult-to-access regions;
- Using mobile telemedicine workstations in the field and during disasters;
- Distant personal monitoring of the health state of disabled and elderly people, in people's homes inclusive;
- Medical staff in-service training, raising the level of their professional skills by presenting new methods of diagnostics and treatment.

The range of equipment manufactured and supplied by the "TANA" company includes a number of hardware devices and systems different in functionality and performance to be specially used in telemedicine centres and offices.

The "TANA telemedicine systems" as provider of telemedicine services, organizes telemedicine consultations of any type – scheduled, urgent or emergent – on a wide range of diseases and medical cases under the three main tariff plans: "Diagnostician", "Consultant" and "Conference of specialist doctors"

Activities of "TANA" and "VITANET" abroad

Apart from participation in large international forums and exhibitions ("Telecom'97, 99", Geneva; "Africa Telecom'98, Johannesburg; "ACEAN'98 Summit", Kuala Lumpur; forum "Eurasia", Brussels, 2001; "InfoCom-2001" and "InfoCom-2002", Moscow, the first Telemedicine and Telecare International Trade Fair, Luxemburg, 2002), the "TANA" Companies Group has been actively interacting with Russian and international public and intergovernmental organizations such as the International Telecommunications Union, the Russian Red Cross, the World Health Organization, the representative office of the UN Development program in Russia and a number of medicine centers in Russia and abroad for the purpose of implementing different telemedicine pilot projects that help form the market of telemedicine services.

We can distinguish three main directions within this activity:

- Bilateral and multilateral cooperation in the field of providing telemedicine services, the purpose of which is not only buying medical consultations abroad for the Russian customers, but selling consultations from Russian medicine centres to the world market;
- The development of projects utilizing telemedicine technologies aimed at the Health care systems of different countries, including former Soviet Republics and African countries. In 2001-2002 the "TANA" Companies Group and "VITANET" public company in cooperation with international experts prepared a number of projects to fight Tuberculosis, AIDS and MALARIA through the use of the mobile telemedicine laboratories and centres in Ethiopia (2001) and Kenya (2002), the relevant project-proposals were submitted to the Global Fund created in 2001 by G-8 to fight Tuberculosis, AIDS and MALARIA in the least developed countries.
- Bilateral Working Groups created under intergovernmental agreements between Russia on the one hand and Germany, Norway, Canada and Israel on the other hand, have become an important lever in cooperation on Telemedicine between the countries. The format of bilateral Working Groups lets both parties successfully share the experience and implement mutual projects.

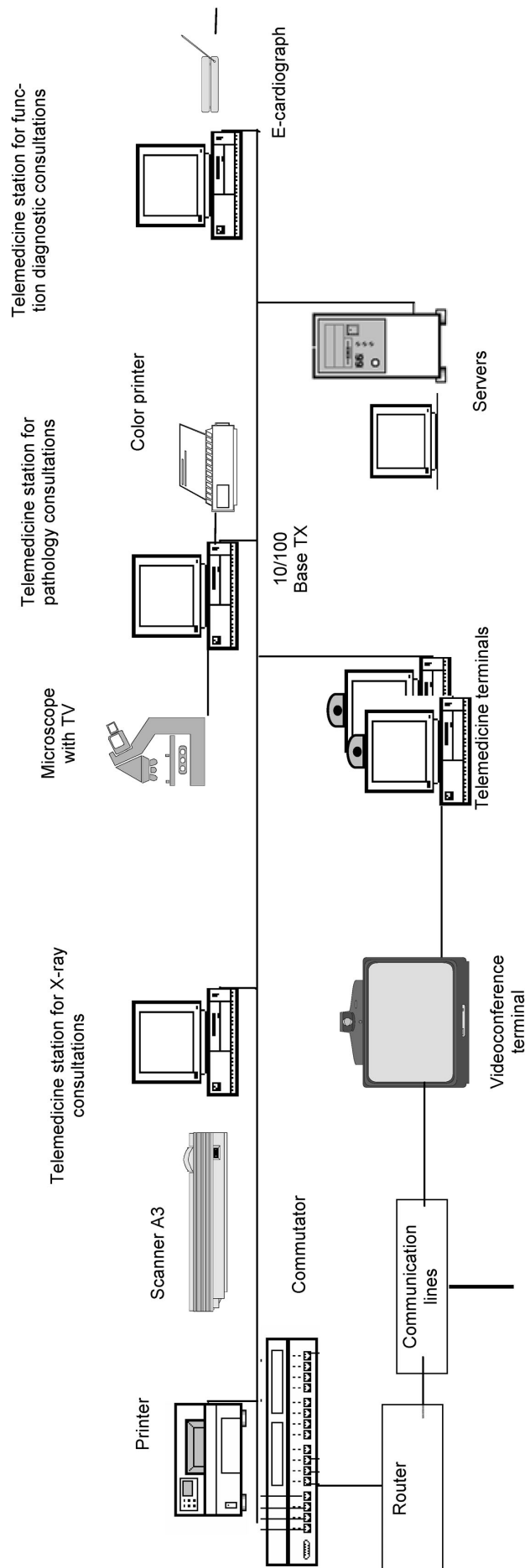


Fig. 1. Configuration and possible arrangement of equipment of telemedicine consulting centre

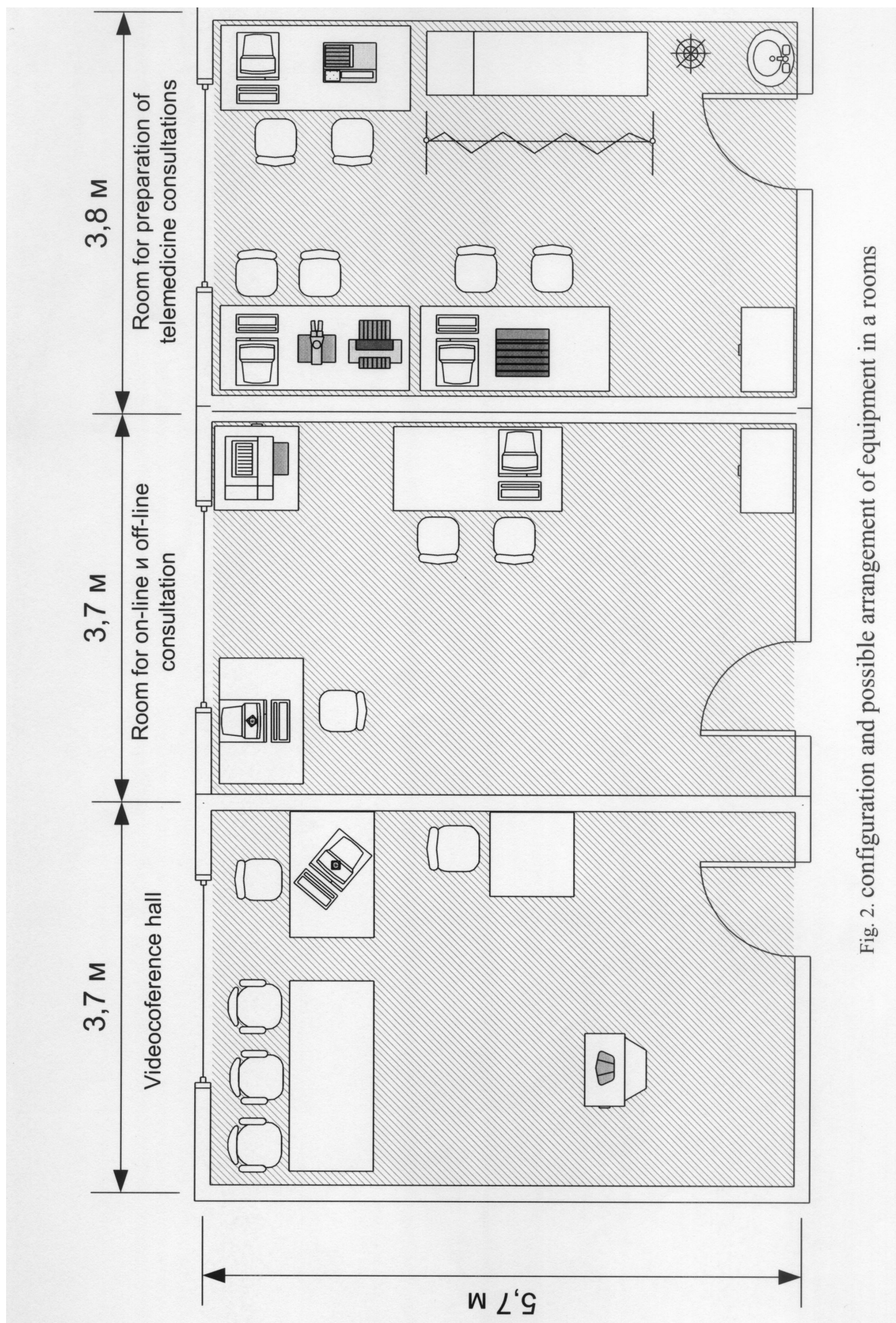


Fig. 2. configuration and possible arrangement of equipment in a rooms

Satellite Radio Broadcasting From Inclined Elliptical Orbit

Robert D. Briskman

The presentation describes the implementation and operation of a satellite radio system in the United States which employs a unique geosynchronous orbit. The satellite radio system broadcasts from orbit 100 audio programs to mobile vehicles (i.e., automobiles, trucks, recreational vehicles, etc.), boats, light aircraft, businesses and homes.

The presentation details the unique satellite orbit and its advantages, since it should be beneficial to both satellite radio systems in other countries or regions (e.g., Europe) and to systems other than satellite radio. A brief summary of the satellites' performance over the past two years is given and compared to pre-launch predicted performance.

The presentation also deals with the necessity of achieving a high service availability (e.g., 99%), the consequent requirement to provide spatial, time and frequency diversity and the necessity for operating mobile terminals with high elevation angles toward the satellite.

The presentation concludes with observations on the current satellite radio service and its predicted future.

SATELLITE RADIO BROADCASTING FROM INCLINED ELLIPTICAL ORBITS

Robert D. Briskman
Technical Executive
Sirius Satellite Radio



Sp
|

Presentation Overview

- Sirius S-DARS System
- Design Requirements and Solutions
- Spacecraft Design Implementation
- Operations
- Conclusions



2

Sp
|

Sirius Satellite Radio System Overview

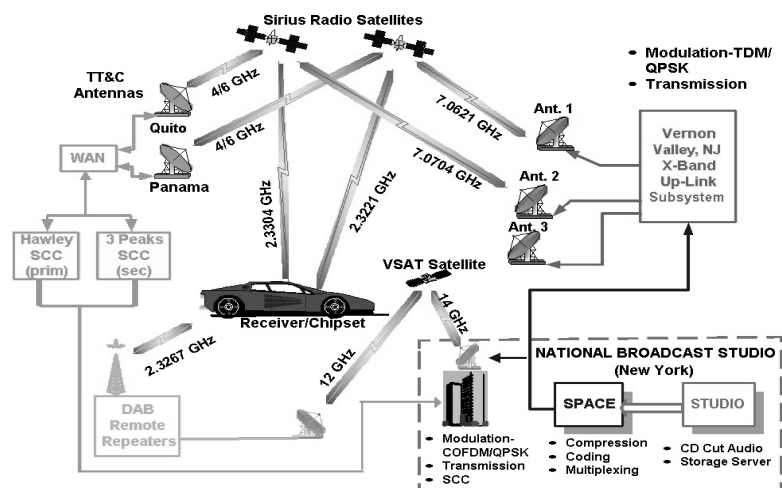
- Satellite Digital Audio Radio System (S-DARS)
 - 100 channels of audio programming
 - Primary market is mobile users in CONUS
- Three satellite constellation using inclined elliptical orbits
 - Constellation provides excellent coverage to mobile users
 - First satellite launched July 2000; constellation completed December 2000
- Satellite payload is a “bent pipe” repeater
 - Broadcast transmission at 2.3 GHz
 - Uplink signal at 7.1 GHz
 - Antenna beams are mechanically steered to maintain coverage



3

Sp
|

Sirius S-DARS Delivery System



4

Sp
|

Outage Mitigation Techniques

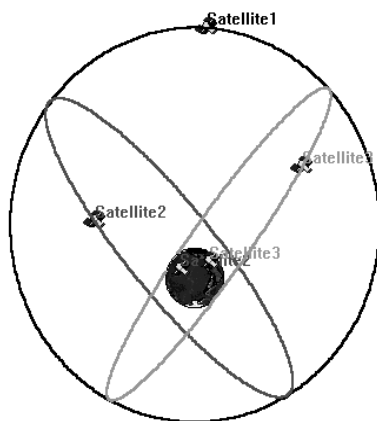
- Spatial Diversity
- Time Diversity
- Frequency Diversity
- High EIRP
- Receiver Equalization
- Constructive Combining
- Terrestrial Repeaters
- **High Elevation Angles**



5

Sp
|

Sirius Constellation Orbital Parameters



- Semi-major axis 42,164 km
- Eccentricity 0.2684°
- Inclination 63.4°
- Argument of Perigee 270°
- RAAN*
 - FM-1 285°
 - FM-2 165°
 - FM-3 45°
- Apogee Altitude 47102 km
- Perigee Altitude 24469 km

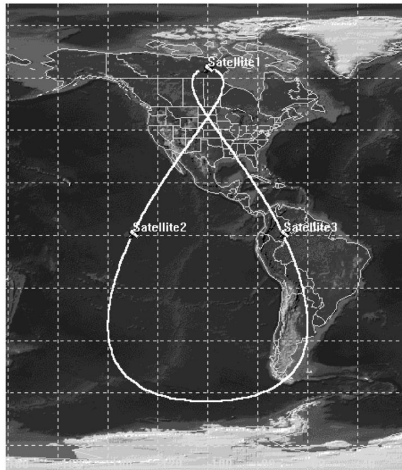
*Right Ascension of Ascending
Node



6

Sp
|

Orbital Ground Track



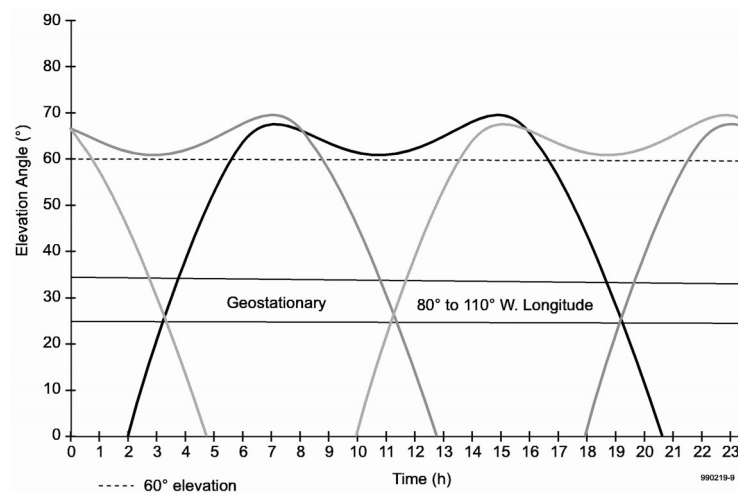
- Satellites are geosynchronous and follow the same ground track
- Two satellites always visible from CONUS
- Broadcast operations for 16 hrs/day
 - From northward equator crossing to southward equator crossing
 - Broadcast uplink from New Jersey
- Broadcast signal greatly reduced in Southern Hemisphere
- TT&C stations located near equator
 - provide continuous coverage of all satellites
 - Quito, Ecuador and Utiwe, Panama



7

Sp
|

Satellite Elevation Angles at Seattle (47° N)

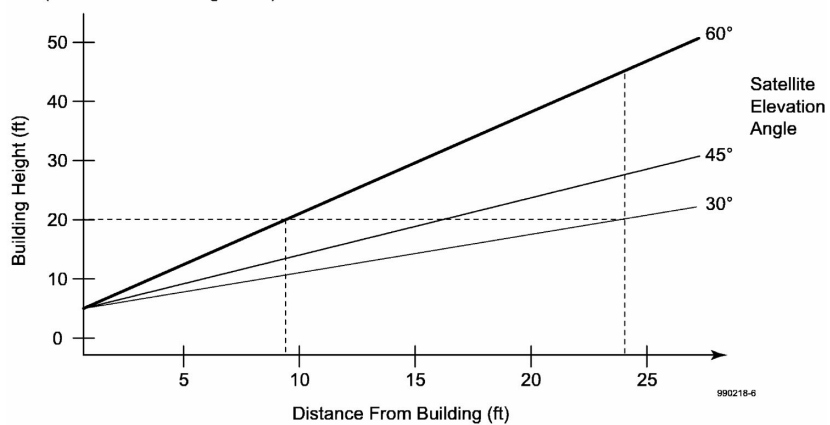


8

Sp
|

Single Satellite Blockage Distance

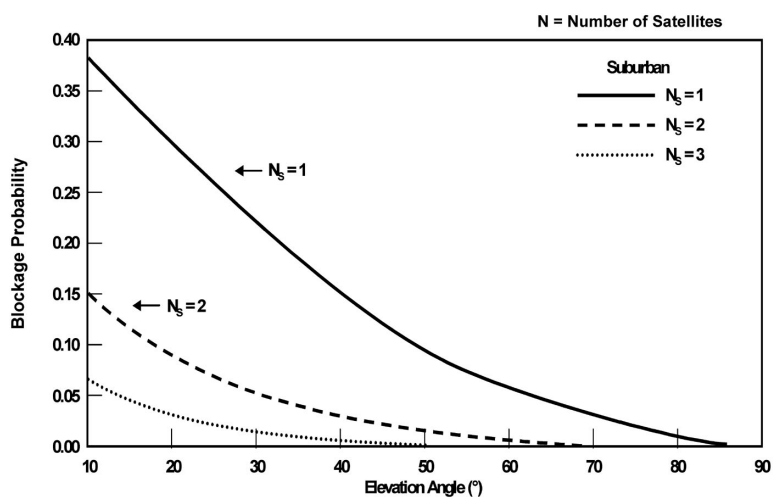
Distance of vehicle from building to avoid blockage
(Vehicle antenna height: 5 ft)



9

Sp

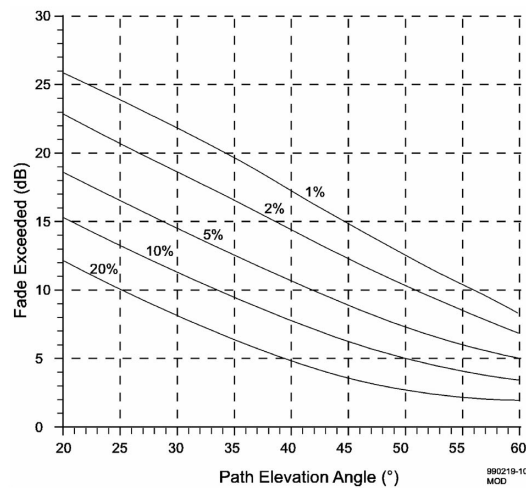
Path Blockage Probability



10

Sp

Foliage Attenuation - Probability of Outage



Design Requirements and Solutions

Requirement	Design Solution
– Sun Angles	Yaw Steering
– Eclipses	Transition to Orbit Normal
– Radiation Environment	Orbit design, shielding, solar array design
– Thermal Environment	No major changes required
– Variation in Slant Range	Self compensating antennas
– Antenna Beam Steering	Orbit propagator, mechanical steering
– Orbital Disturbance Effects	Orbit propagator, mission design
– Variation in Orbital Rates	Orbit propagator
– Variable Earth Size	Orbit propagator; earth sensor design
– Launch and Orbit Raising	No major changes required

Sun Angles in Inclined Orbits

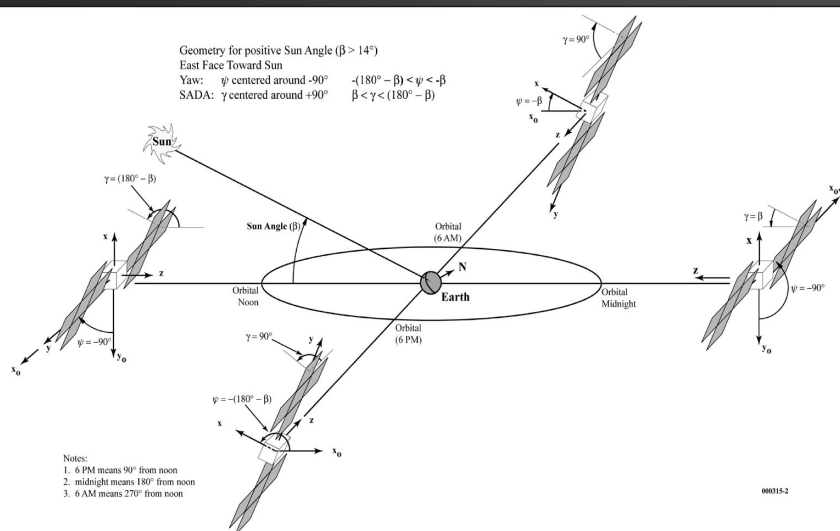
- Sun angles can reach 87° , nearly parallel to solar arrays
- Two degrees of rotational freedom required for solar arrays
 - Sirius design uses spacecraft body rotation: “yaw steering”
- Beta angle is defined as angle between earth sun vector and satellite orbital plane
 - Yaw steered when Beta angle exceeds 14°
- Yearly sequence :
 - Yaw steering for approximately 4.5 months
 - Orbit normal for approximately 1.5 months (including eclipse season)
 - Yaw steering for approximately 4.5 months
 - Orbit normal for approximately 1.5 months (including eclipse season)



13

Sp
|

Yaw Steering Geometry



14

Sp
|

Eclipses, Radiation and Thermal Environments

- Eclipses
 - Two eclipse periods each year which are RAAN dependent
 - Season with long eclipses up to 80 minutes
 - Season with short eclipses up to 63 minutes
 - Each eclipse season may vary from 17 days to 31 days
- Radiation Environment
 - Spacecraft grazes the outer Van Allen belt near perigee
 - Higher proton levels, lower electron levels, greater total radiation dose
 - Minor shielding added to several electronic units
 - Solar arrays designed to compensate for additional degradation
 - Optical sensors validated for the environment
- Thermal Environment
 - Yaw steering results in less severe thermal environment than GEO mission



15

Sp
|

Antenna Performance

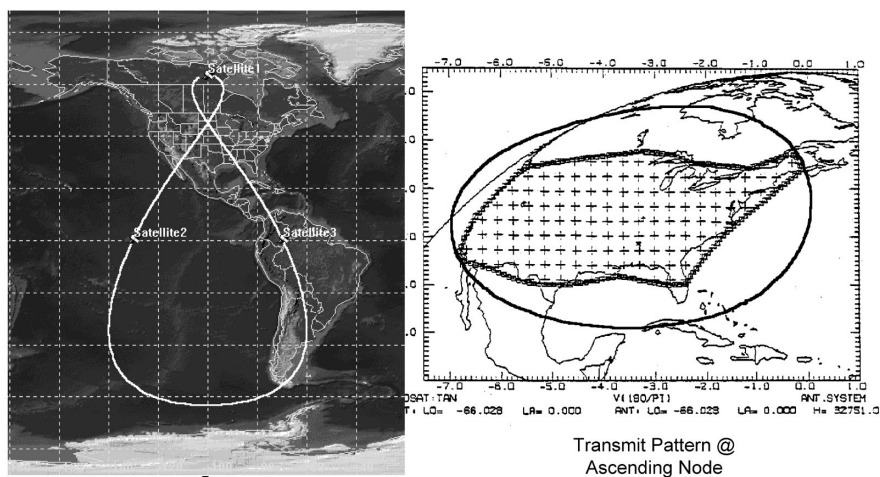
- Coverage
 - X-band uplink Circular coverage including New York and Denver
 - S-band downlink Elliptical coverage of CONUS
- Beam Steering
 - X-band uplink
 - Two axis mechanical steering of main reflector compensates for orbital ground track
 - S-band downlink
 - Two axis mechanical steering of main reflector compensates for orbital ground track
 - Rotation of subreflector compensates for yaw steering
- Self compensation
 - Edge of Coverage flux density remains relatively constant even though peak flux density varies by ~3 dB



16

Sp
|

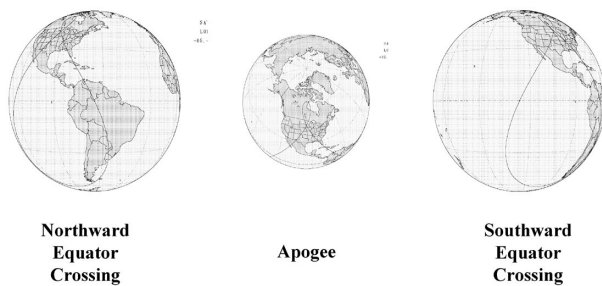
Transmit Antenna Coverage



17

Sp
|

Earth View from Sirius Orbit



18

Sp
|

Orbit Propagator

- High accuracy on-board ephemeris
 - Continuously generates rate and position data
 - Updated every four to six weeks
- Drives all continuously variable functions
 - Solar arrays
 - Antenna mechanisms
 - Inputs for variable earth size
 - Variable body rotation while yaw steering
 - Calculation of sun-moon intrusions



19

Sp
|

Performance and Design Comparison GEO vs. Inclined Elliptical Orbit Spacecraft

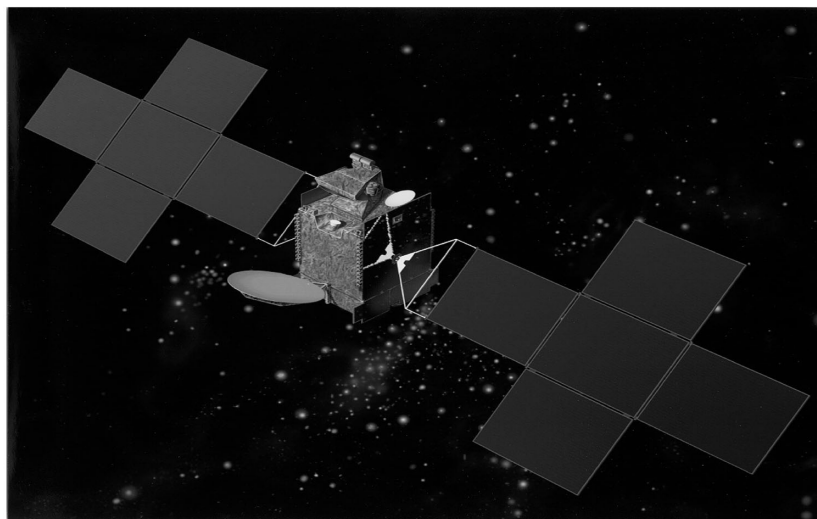
Parameter	Geostationary	Inclined Elliptical
EIRP	60.3 dBW	60.3 dBW
G/T	1.0 dB/K	-0.1 dB/K
Pointing accuracy	0.1°	0.35°
Dry Mass	1300 kg	1575 kg
Separated Mass	3525 kg	3900 kg
RF power (operating)	2.5 kW	4 kW
DC power - EOL		
Solar Array	7.5 kW	8.5 kW
Battery	7.5 kW	8.8 kW
Control System	3-wheel mom bias	4-wheel mom bias On-board orbit propagator
Control Modes	Orbit Normal	Orbit Normal Yaw Steering
TX Antenna	Fixed Gregorian Gain 27.8 dBi; Cross-pol 24 dB	Gregorian; two axis steering 360° rotating shaped subreflector Gain 27.2 dBi; Cross-pol 28 dB
RX Antenna	Fixed offset fed	Offset fed; two axis steering
Solar array	2x4 panel HES	2x5 panel HES
Battery	2x32 cell - 149 AH	2x34 cell - 178 AH
TT&C	X, C and S bands CONUS ground station Limited motion antennas	C and S bands 2 near equatorial ground stations Full motion antennas
Launch Vehicle	Ariane	Proton



20

Sp
|

Fully Deployed Satellite



21

Sp
|

Spacecraft Design Implementation

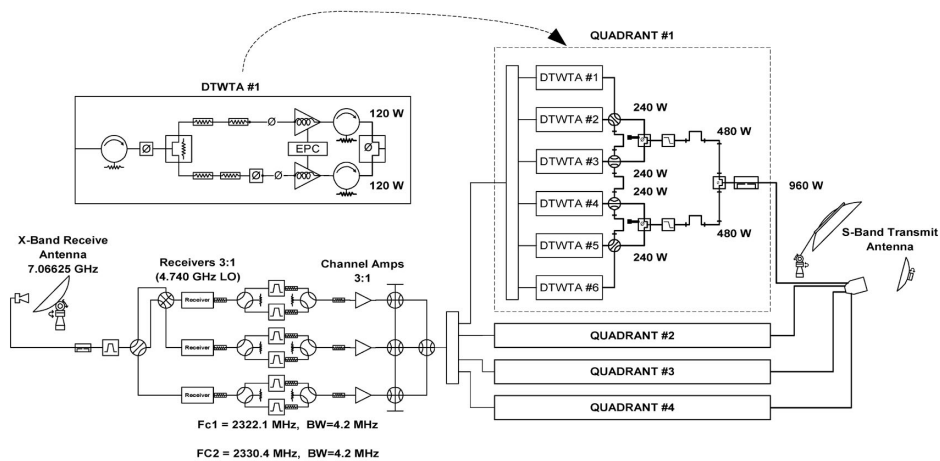
- Spacecraft
 - SS/L 1300 bus modified for inclined orbit operations
 - 15 year orbital lifetime
 - High reliability design: Ps payload = 92%, Ps bus = 87%
- Payload
 - “Bent pipe” repeater
 - Triple redundant input section
 - Four quadrants of 6:4 stack redundant Dual TWTAs
 - 32 TWTs phase combined to yield ~4 kW RF output
- Bus
 - Momentum biased three axis control system
 - Integrated bi-propellant propulsion system
 - High efficiency silicon solar arrays and Nickel-Hydrogen batteries



22

Sp
|

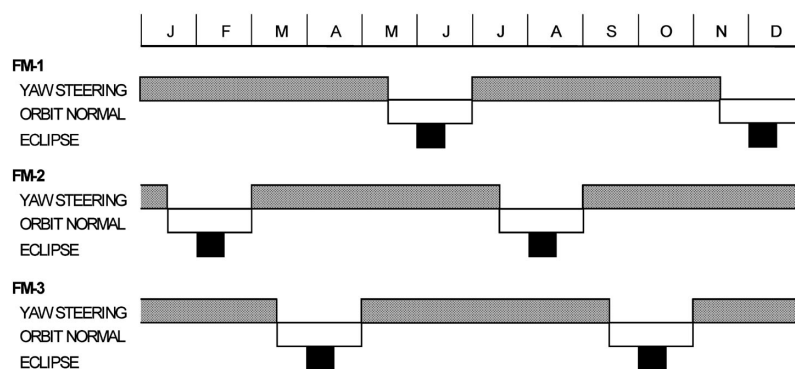
Payload Simplified Block Diagram



Operations

- The Sirius Radio constellation became operational at the end of 2000
 - Constellation performing flawlessly
- Highly automated satellites; easy to operate and maintain
 - Twice daily configuration by time-tagged commands
 - Automatic scan inhibit logic reduces operator workload
- Payload operations for 16 hrs/day
 - 8 hours available for station-keeping, reconfiguration or redundancy switching
- Separation of orbital RAANs result in staggered high activity periods
 - Different timing for eclipses and orbital maneuvers for each satellite

Yearly Operational Timeline



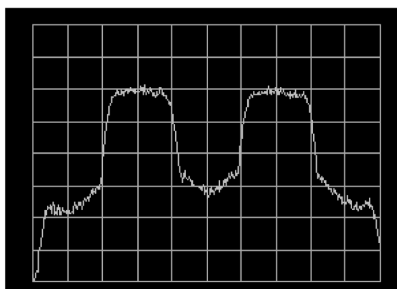
25

Sp
|

Communications Payload Performance

- The satellite EIRP is continually monitored and displayed in the Satellite Control Center in New York City.
- Periodically accurate measurements are performed using a calibrated tracking antenna

TDM1 and TDM2 Signal Spectrum Display



Payload EIRP Measurements in

Atlanta, GA

Date	Satellite and Orbital Location	Average Measured EIRP (+/- 0.3dB)	Min. Predicted EIRP (+/- 0.47dB)
10/11/01	F-1 (Ascending Node)	64.3 dB	64.2 dB
10/12/01	F-2 (Ascending Node)	64.0 dB	63.8 dB
10/12/01	F-3 (Apogee)	63.4 dB	62.7 dB



26

Sp
|

Orbit Control and Propellant Performance

- The accuracy of orbit control and the consequent on-board fuel expenditure have been excellent.

Constellation Orbital Performance

Orbital Elements	Nominal Value	Tolerance	Current Stationkeeping Performance
Semi-Major Axis (km)	42164		
Eccentricity	0.2684	+/- 0.005	+/- 0.003
Inclination (°)	63.4	+/- 0.5	+/- 0.2
RAAN Spacing (°)	120	+/- 0.5	+/- 0.4
Argument of Perigee (°)	270	+/- 5.0	+/- 1.5
Phasing (Minutes)	0	+/- 15	+/- 12
Longitude (° West)	96	+/- 0.5	+/- 0.4

Constellation Propulsion Performance

SC Parameter	FM-1	FM-2	FM-3
Propellant at BOL, Kg	1455	1450	1445
Propellant Remaining, Kg	1350	1315	1380
Predicted Propellant Life, ~ yrs	24	21	29
Number of Maneuvers Performed to Date	32	45	23

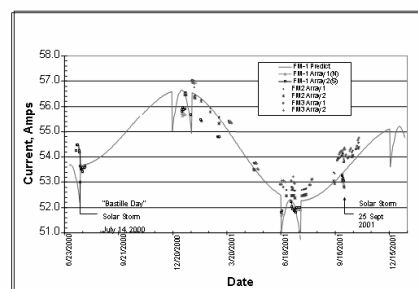


Sp
|

Satellite Solar Array Performance

- The ten-panel solar array degradation due to radiation has been equal or better than predicted.

Constellation Solar Array Performance Data



28

Sp
|

Conclusions

- The Sirius Satellite Radio constellation marks the first use of DARS broadcasting in the United States
- The three high power direct broadcast satellites will provide service for millions of subscribers.
- The Sirius Radio system is the world's first satellite broadcast system using non-geostationary orbits.
- The use of inclined elliptical orbits coupled with multiple modes of transmission diversity provides notable advantages for broadcast service to the mobile market.
- Pioneering technology was developed and implemented by Sirius Satellite Radio and Space Systems/Loral in order to accomplish this unique achievement



Motion Picture Transmission System from Ambulance

Atsushi Nakajima

National Aerospace Laboratory of Japan

7-44-1 Jindaiji-higashi-machi, Chofu-shi, Tokyo 182-8522, Japan

E-mail:nakajima@nal.go.jp

Abstract

Since 2000, National Aerospace Laboratory of Japan(NAL), cooperated with CRL, Tokai University Institute of Medical Sciences, NEC Corporation, Tasada Works and Astro Research Corporation have been developed motion picture transmission system from ambulance via satellite for the improvement of lifesaving rate and reduction of sequelae on serious illness patients who are transported by ambulance. For the achievement of this purpose, we have been developing medical equipments onboard the ambulance, quasi-zenith satellite tracking system and also studying highly inclined orbits(quasi-zenith satellite orbit), small satellite system, etc. This paper describes the overview of this project studied during the past 3 years(FY 2000-2002).

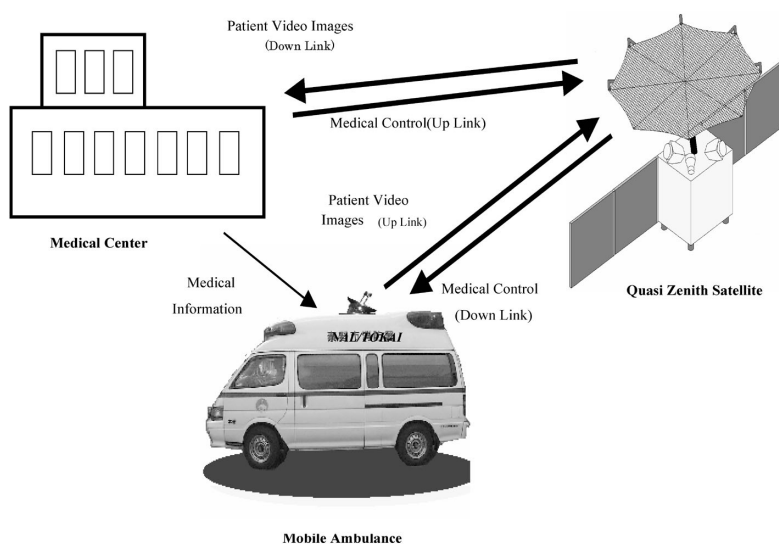
Motion Picture Transmission System from Ambulance

A.Nakajima, T.Yanagisawa,
S.Yoshihara, T.Hoshino and S. Kawamoto

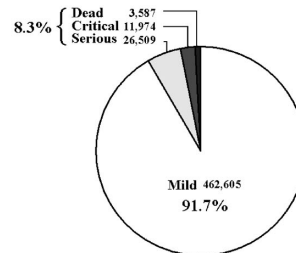
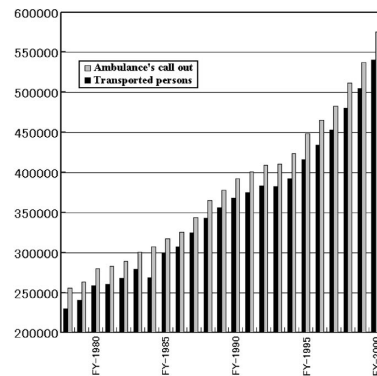
National Aerospace Laboratory of Japan

Small Satellite Symposium 2003
March 12, 2003

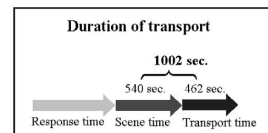
Patient Motion Picture Transmission from Ambulance



Number of Emergency Transportation in Tokyo, Classification of Severity and Average Trans. Time

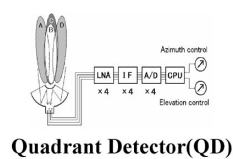


Classification of the severity



Experimental Ambulance and related Communication / Display System

Developed by Tokai University, NEC and Tasada Wroks



Quadrant Detector(QD)



8 G H z Q D Antenna



Variable Time-delay Digital
Communication Satellite



Experimental Ambulance



Listing Display



Light Reflex Data



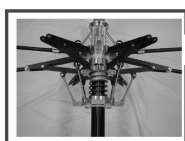
Screen at Medical Center

Image Data Examples for Transmission

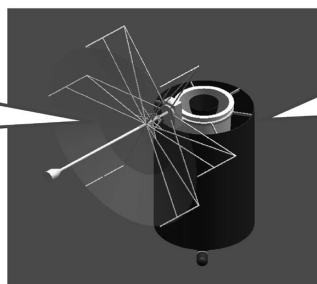
Airway, Light Reflex, ECG(Electrocardiogram) and Ultrasonic Image



Subsystems Developed by NAL, Toshiba and Astro Research Corp.



**Deployable Mesh
Antenna**



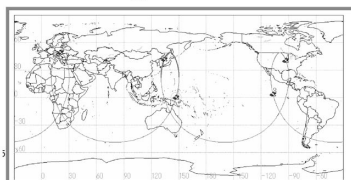
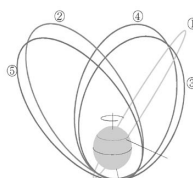
**Small Satellite Design for
Technology Demonstration**



**Magnetic Bearing
RW**



X-Y Gimbal

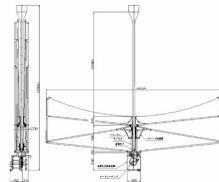


Quasi-Zenith Orbit

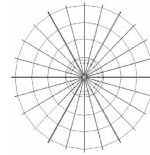


Tracking System

Deployable Mesh Antenna



Stow/Deployment



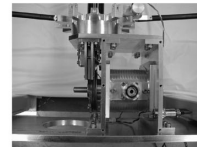
Symmetrical Parabola with 24 ribs



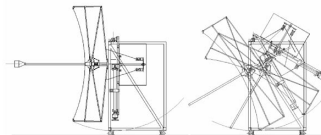
Overview



Deploy Mechanism



Rotary Damper

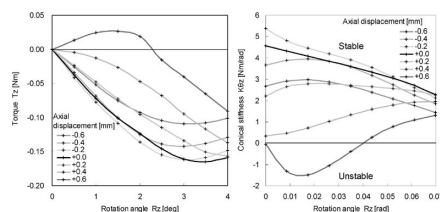


Deployment Experimental Apparatus

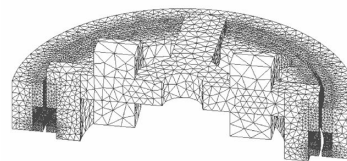
Item	Characteristics	Remarks
Reflector Type	Symmetrical Parabola	
Diameter	$\phi 2 \text{ m}$	
Focal Length	1 2 0 0 mm	
Deployed Size	7 4 7 \times 2 1 0 0 mm	
Stowed Size	1 7 0 0 \times 1 6 0 mm	
Truss Size	$\phi 1 0 \text{ mm} \times t 0.4 \text{ mm}$	CFRP Pipe
Total Mass	12.0 kg	

Design Specification

Small Magnetic Bearing Reaction Wheel



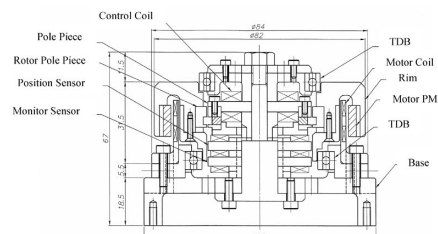
Conical Axis Stability Analysis



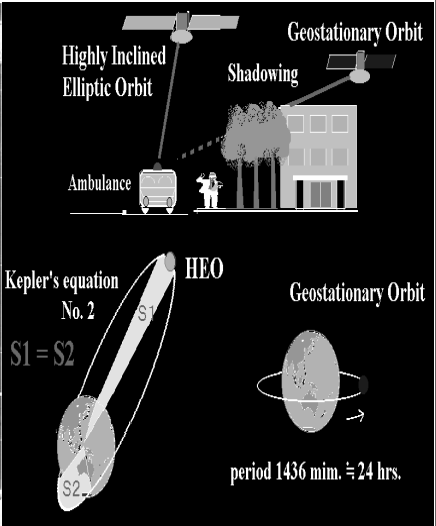
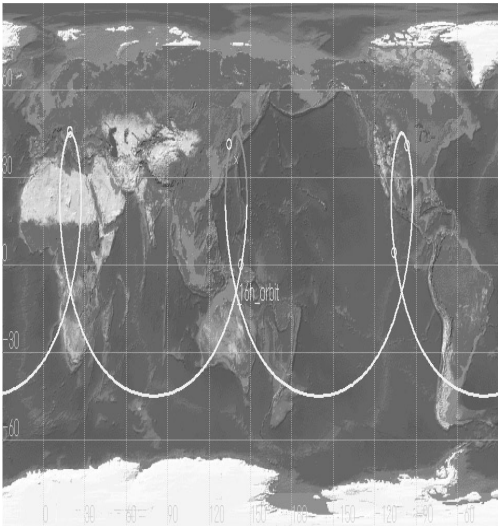
FEM Model



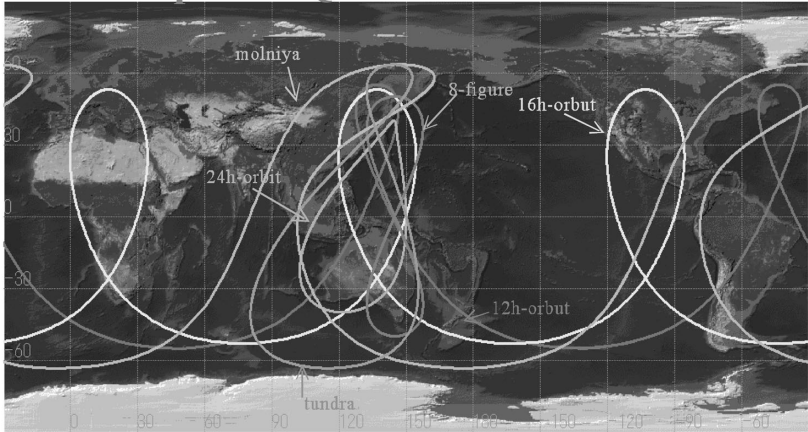
MBRW Experimental Model



Quasi-zenith Orbit
for Continuous Communication Link



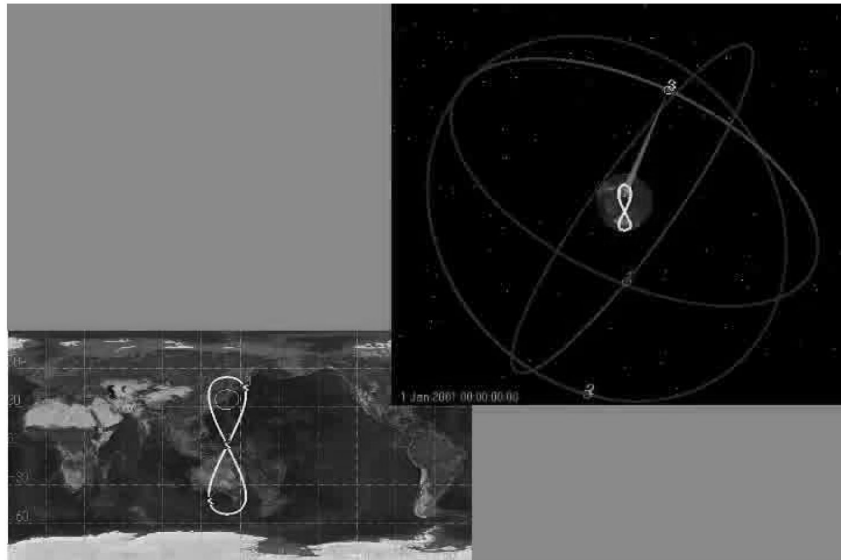
Examples of Quasi-Zenith Orbit



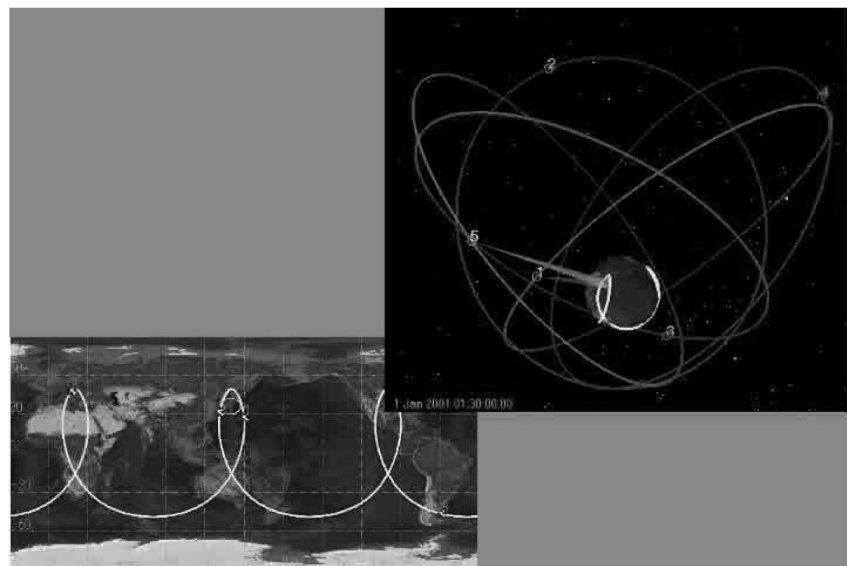
orbital period	orb type	Time (hrs)	a (km)	i (deg)	e	perigee (km)	apogee (km)	dΩ (deg/year)	dω (deg/year)
12h	molniya	4.2	26600	63.435	0.75	271.858	40171.86	-57.9146	-0.00023
12h	12h-orbit	10.6	26600	55	0.75	271.858	40171.86	-74.2788	41.76085
16h	16h-orbit	12.0	32177	55	0.6	6492.763	45105.48	-19.0743	10.72391
16h	tund	4.0	42160	63.435	0.75	4161.858	67401.86	-12.5471	-5E-05
24h	8f	8.1	42160	50	0	35781.86	35781.86	-4.7343	3.925239
24h	24h-orbit	10.2	42160	40	0.2	27349.86	44213.86	-5.96129	7.525581

Tokyo

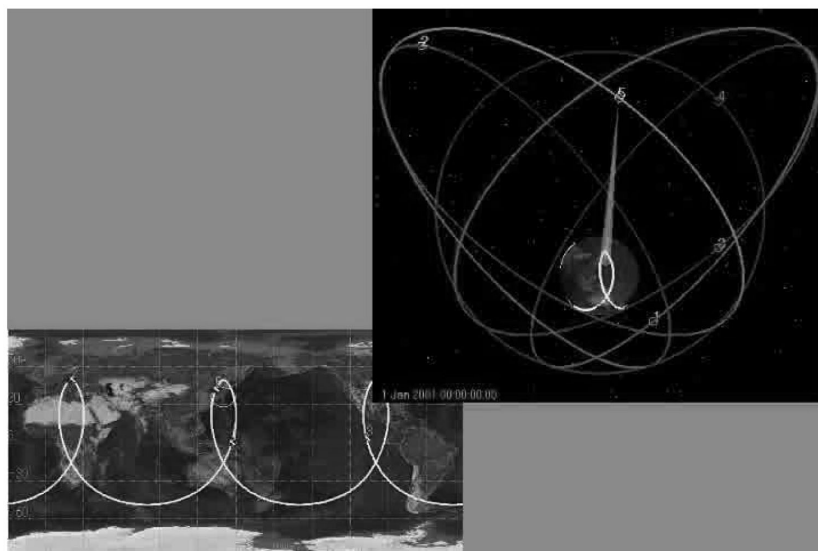
8-Figure Orbit



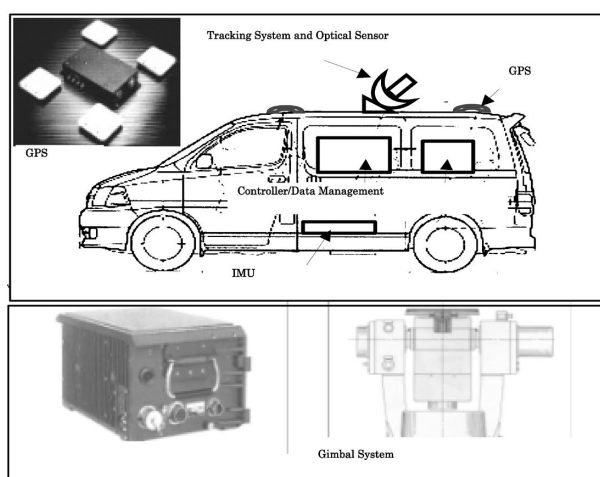
16-Hour Orbit (Viewed from Inertial Frame)

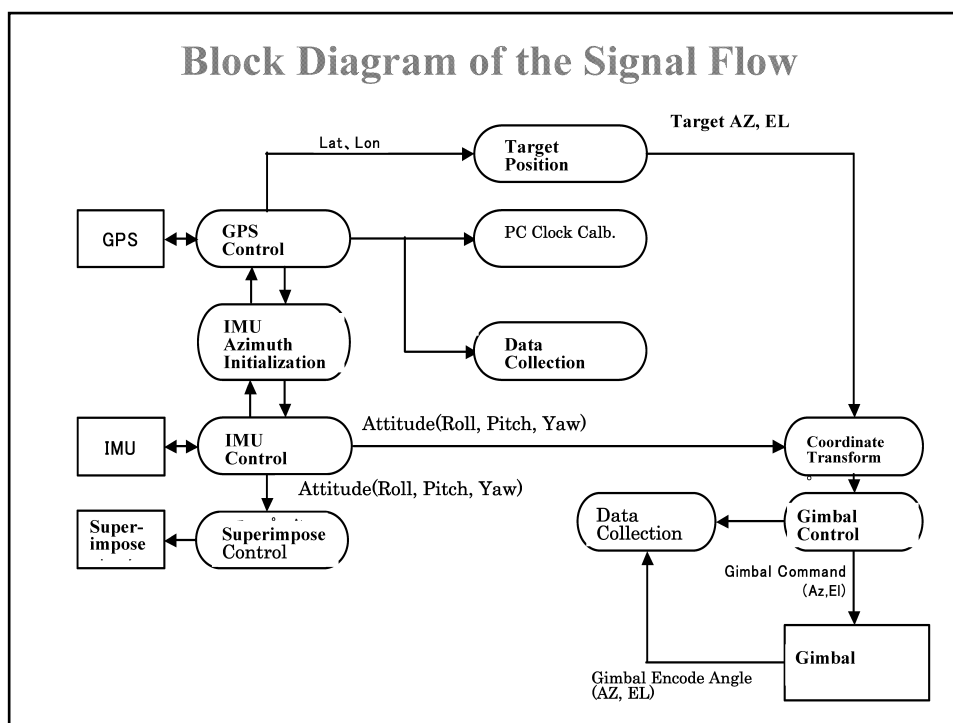


16-Hour Orbit (Viewed from EarthFixed Frame)



Tracking System for the Evaluation of Tracking Accuracy





Characteristics of Tracking Equipments

IMU

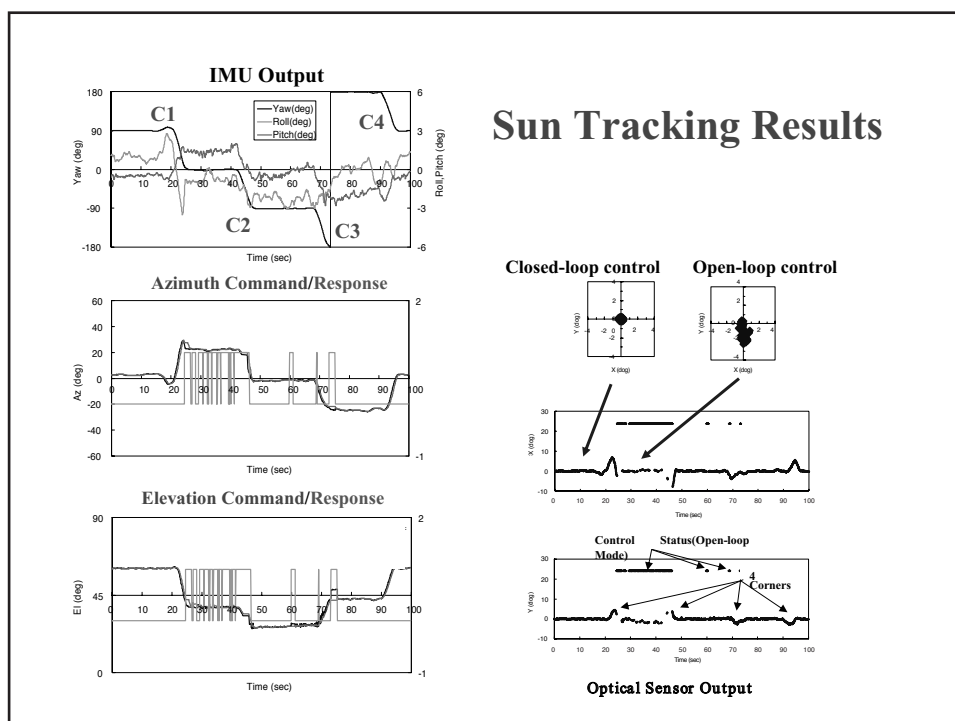
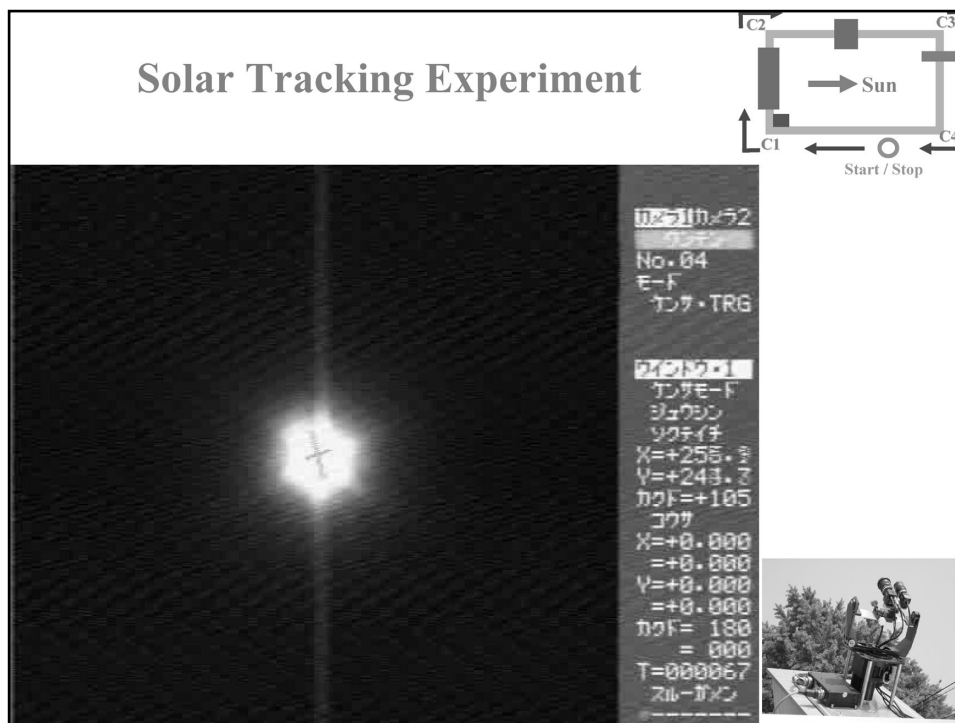
Items	Characteristics
Model	TA7571(Tamagawa Seiki) 3 FOGs and 3 accelerators
Attitude	
Roll	$\pm 180^\circ$ ($\pm 0.2^\circ$ Accuracy)
Pitch	$\pm 90^\circ$ ($\pm 0.2^\circ$)
Yaw	$\pm 180^\circ$ ($\pm 0.2^\circ$)
Rate	$\pm 200^\circ/\text{sec}$ ($\pm 0.3^\circ/\text{sec}$) for 3 axes
Accelerator	30m/s^2 ($\pm 0.03\text{m/s}^2$)
Frequency	200 Hz(5 ms)
Dimension	220x200x185 mm
Weight	8.2 kg

Gimbal

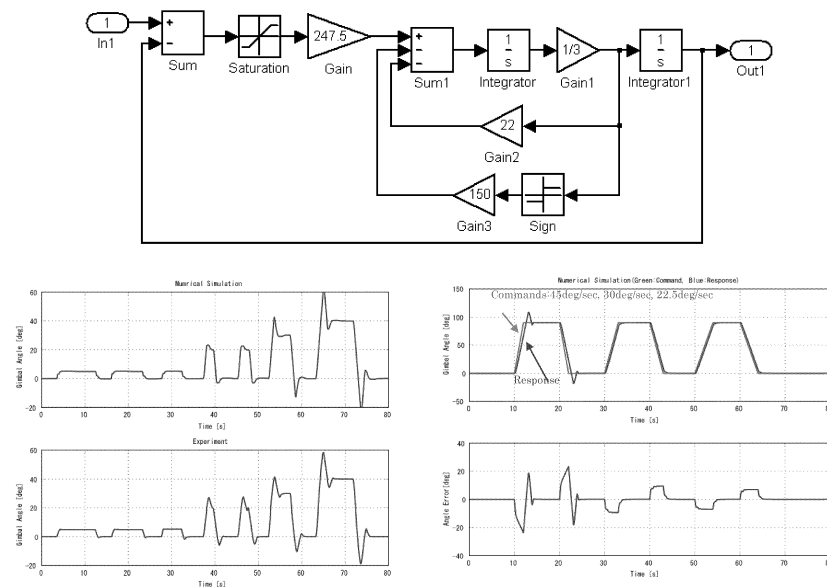
Items	Characteristics
AZ/EL Model	AL-1610(Orbit Co.)
Rate AZ/EL	$72^\circ/\text{sec}$, $120^\circ/\text{sec}$
Range AZ/EL	Continuous, $-12\sim 90^\circ$
Torque AZ/EL	15Nm, 3Nm
Dimension	$\Phi 140 \times 300$ mm
Weight	8 kg
X-Y Model	NAL-01(IHI Aerospace)
Rate X/Y	$70^\circ/\text{sec}$
Range X/Y	$-60\sim +60^\circ$
Dimension	200x220x255 mm
Weight	10 kg

GPS

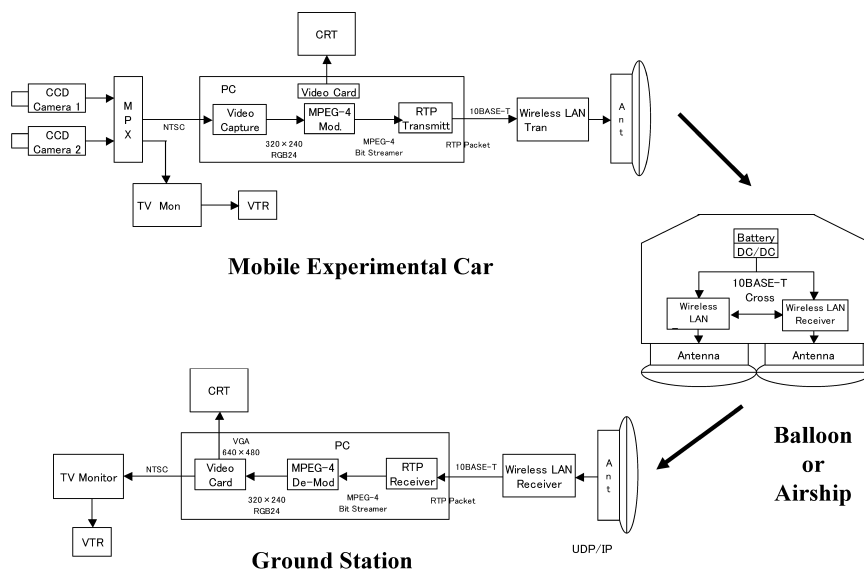
Items	Characteristics
Model	TANS Vector(Trimble Japan)
Attitude	0.3° (RMS) at 1-m baseline
Position	2-5 meters(Horizontal) 5-8 meters(Vertical)
Velocity	0.2m/sec (RMS)
Dimension	127x207x56 mm
Weight	1.4 kg(RPU) 0.18 kg(Antenna)



System Model and Simulation

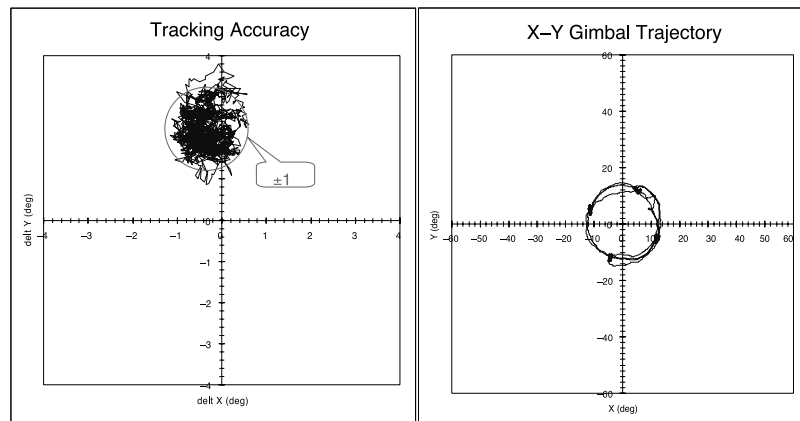


Picture Relay Demonstration using Balloon





Moon Tracking Experimental Results (Open Loop)



Movie Transmission via Balloon



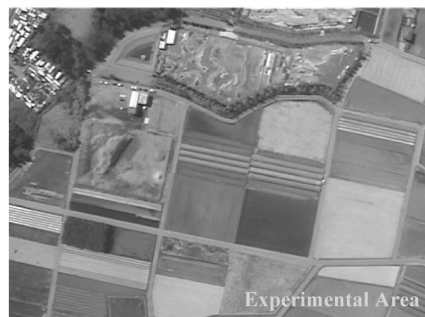
Wireless LAN : IEEE802.11b
1.5 Mbps

Balloon Altitude : 500 m
MPEG4 Compression

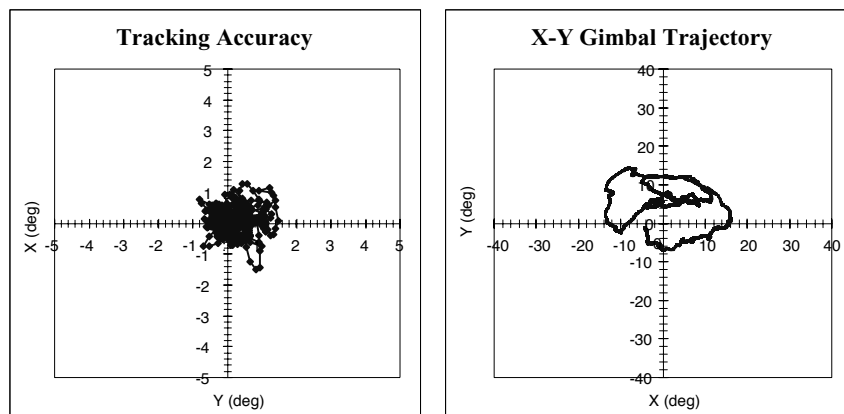
Sender



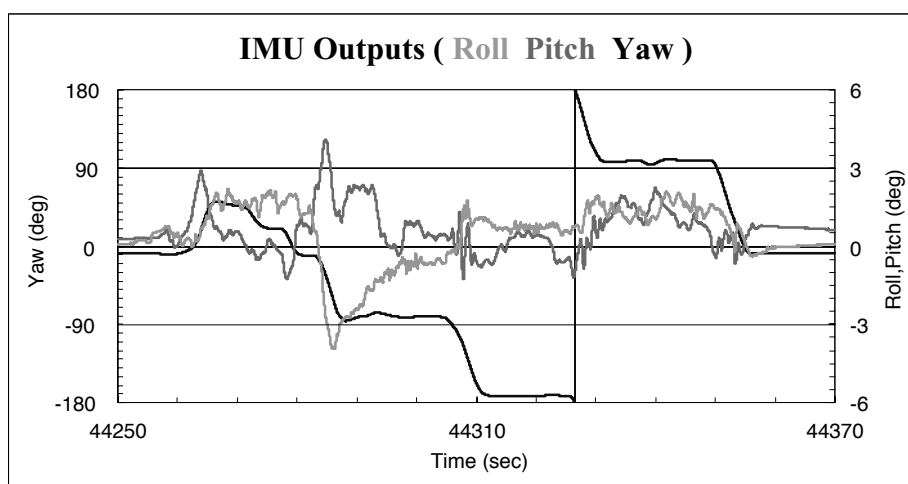
Receiver

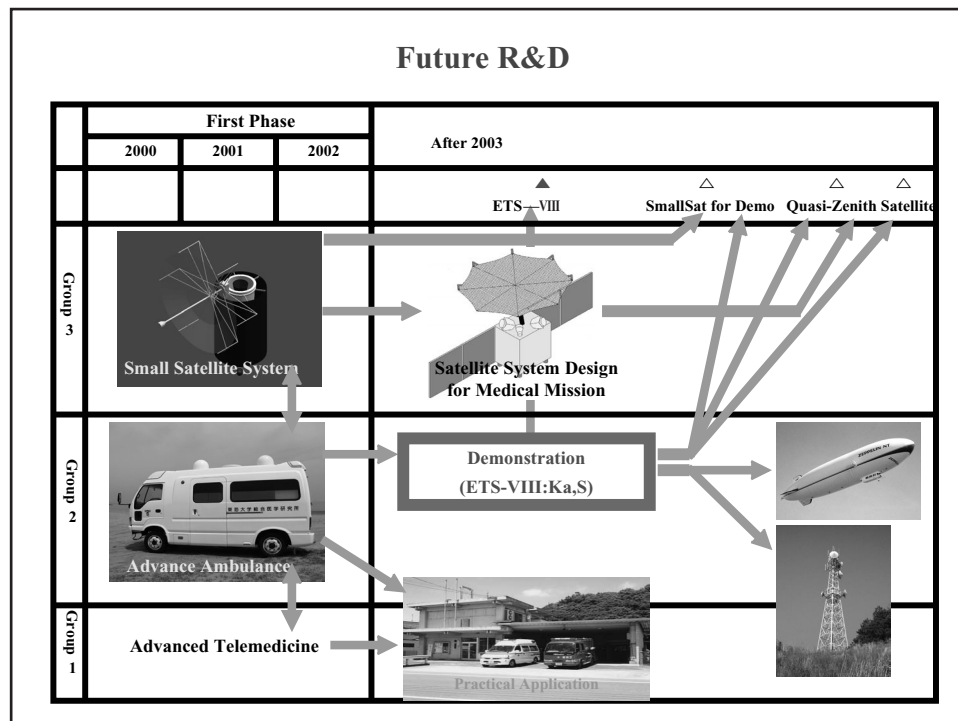


Experimental Results



Attitude Trajectories of the Car





FedSat
Ka band Communications Experiments

A/Prof Sam Reisenfeld
Cooperative Research Centre for Satellite Systems
Faculty of Engineering
University of Technology, Sydney
1 Broadway
Broadway, NSW 2007
AUSTRALIA
E-mail: samr@uts.edu.au

Abstract: FedSat is a 58 kg, 50 cm cube microsatellite launched into a 800 km sun synchronous orbit on 14 December 2002. FedSat is equipped with an experimental communications system capable of UHF and Ka band operation. FedSat also has several scientific payloads including a magnetometer, GPS receiver, star camera, and a high performance computer.

The Ka band earth station requirements for the FedSat Ka band communications system are quite demanding in terms of antenna pointing and Doppler tracking. The University of Technology, Sydney has designed and fabricated two Ka band earth stations which meet these requirements. The earth stations utilize some novel approaches to frequency and spatial tracking. A key element of the earth stations is the use of high speed digital signal processing provided by two Texas Instruments TMS320C6711 processors. Earth stations are being operated from the University of Technology, Sydney and the University of South Australia, in Adelaide.

Experiments will be run on the FedSat satellite during its three year operational life. The Ka band experiments include spatial and frequency tracking, bit error rate characterization and atmospheric attenuation data collection and modeling.

The Ka band transponder has two major modes of operation. These are an unmodulated beacon mode and a bent pipe transponder mode. The transponder mode is capable of supporting a 128 kbit/s QPSK modulated, convolutionally encoded data link.



FedSat

Ka band Communications Experiments

A/Prof Sam Reisenfeld
CRC for Satellite Systems
University of Technology, Sydney
1 Broadway
Broadway, NSW 2007
AUSTRALIA

Small Satellite Symposium, 2003, Tokyo, 12 March 2003 1

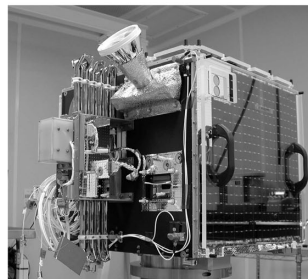
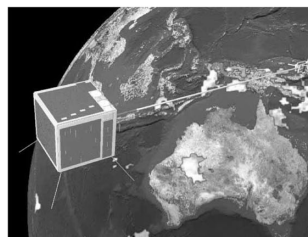


FedSat Satellite

Japanese H-IIA Launch, 14 December 2002



- **58 kg, 50 cm cube, micro-satellite**
- **800 km, sun synchronous, near polar orbit**
- **15.15 minute maximum pass time**
- **Communications Experiments**
 - UHF (bent pipe transponder and baseband processor)
 - Ka band (downlink beacon and bent pipe transponder)
- **Scientific Payloads** (magnetometer, GPS receiver, star camera, high performance computer)





Goals of FedSat



- Build-up of Australian satellite capability and technology
- Orbital operation of a space science and communications experimental test-bed
- Satellite education
- Growth of a satellite and earth station industry
- Preparation for commercialisation and future projects

3




The FedSat Mission





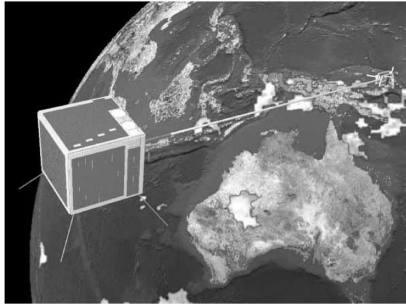
- Satellite Communications Experimental System
 - UHF
 - **Ka band (30 GHz uplink and 20 GHz downlink)**
 - **New commercial and defence communications**
 - **Large available bandwidth for high data rate communications**
- Scientific Experiments
 - **GPS receiver**
 - **Star Camera**
 - Newmag Magnetometer
 - High Performance Computer

4



A/Prof Sam Reisenfeld
 Faculty of Engineering
University of Technology, Sydney
 1 Broadway
 Broadway, NSW 2007
AUSTRALIA





The UTS Ka band Earth Station

The FedSat Satellite

5



**CRCSS Ka band
Communications Organisation**



**QUT
GPS
Receiver**

- Dr Rodney Walker
- Dr Yanming Fang

Communications Node

- UTS (Ka Earth Station)
 - A/Prof Sam Reisenfeld
- CSIRO-TIP (Ka band FedSat Transponder)
 - Dr Andrew Parfitt
 - Dr Trevor Bird
- Univ of South Australia (Baseband Processor)
 - Prof Bill Cowley

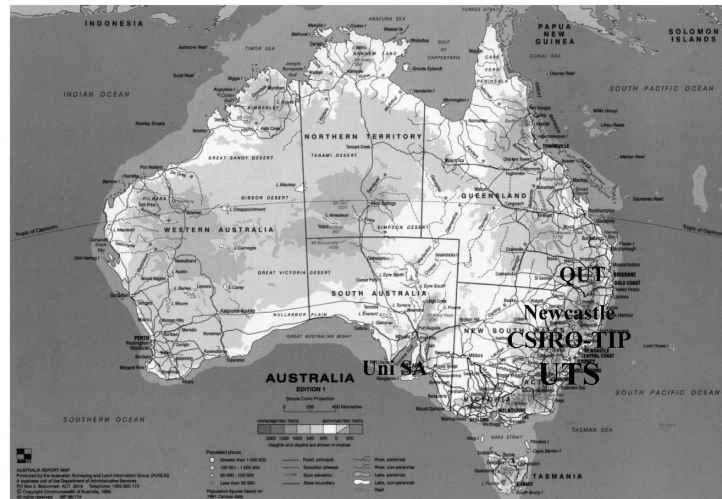
**Newcastle Univ
Star
Camera**

- Prof Brian Fraser

6



CRCSS Ka band Organisations



7



UTS Organisation



Administration

Prof Ross Milbourne, Vice Chancellor
 Prof Lesley Johnson, Pro Vice Chancellor, Research
 Prof Archie Johnston, Dean, Faculty of Engineering and Board Member
 Prof Rod Belcher, A/Dean, Research, Faculty of Engineering

Faculty and Staff

- **A/Prof Sam Reisenfeld, Program Director**
- **Mr Ray Clout, Research Lab Manager**
- Mr Peter Farleigh, Technical Officer
- Mr Youn Sik Kim, Software Engineer
- Mr Andrew Thoms, Software Engineer
- Mr Thorsten Kostulski, Electronics Engineer
- Mr Chris Chapman, Mechanical Engineer
- Mr Alan Brady, Civil Engineering
- Dr Tim Aubrey, Electronics Engineer
- Dr Tom Osborn, Systems Engineer
- Dr Michael Eckert, Systems Engineer
- Prof John Reizes, Financial Officer

PhD Students

- Dr Keith Willey
- Mr Elias Aboutanios
- Mr Kwok Chung
- Mr Sithamparanathan Kandeepan
- Mr Steven Wang
- Mr Jeffrey Tsui

8

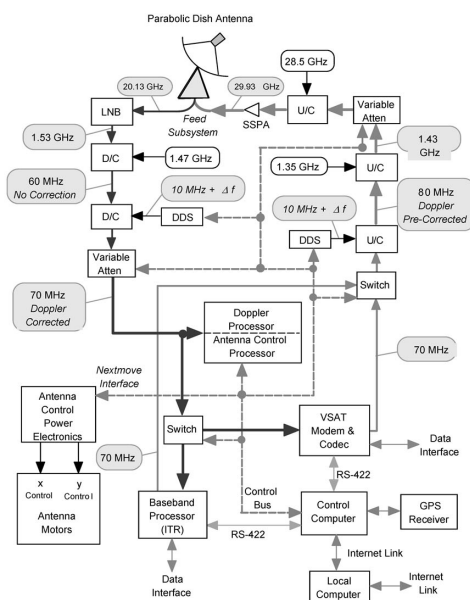


FedSat Ka Band Communications



- Beacon Mode
 - Unmodulated Carrier Transmission
 - 20 GHz Downlink Transmission
- Non-regenerative repeater mode
 - Frequency translation, hard limiting, and amplification (30 GHz U/L and 20 GHz D/L)
 - up to 128 kbits/s data rate
 - QPSK modulation and rate 1/2, constraint length 7, convolutional encoding
 - $BER \leq 10^{-6}$

9



**UTS Ka Band Earth Station
Block Diagram**

10

Earth Station Indoor Electronics



11



Earth Station Characteristics



$EIRP = 51.5 \text{ dBW}$ (Transmit Power = 2 Watts)

$G/T_s = 22.0 \text{ dB/K}$ (Antenna Temp = 50 K,
Feedline loss = 0.5 dB
LNB noise figure = 1.5 dB)

Transmit Centre Frequency = 29.93 GHz

Receive Centre Frequency = 20.13 GHz

12



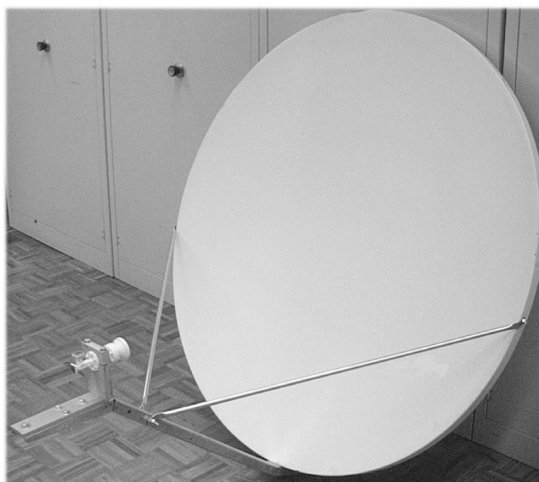
Earth Station Antenna Size



- 1.2 meter offset parabolic dish reflector antenna
- **Compromise between maximising antenna gain and providing a sufficiently wide beamwidth for spatial tracking**
- **30 GHz (uplink) characteristics**
 - Antenna gain = 48.5 dBi
 - 3 dB beamwidth = 0.58 degrees
- **20 GHz (downlink) characteristics**
 - Antenna gain = 45.4 dBi
 - 3 dB beamwidth = 0.88 degrees

13

1.2 m Offset Parabolic Reflector Antenna and Feed (Prodelin Corp)



14



Spatial Tracking



- Open loop tracking method
- Spacecraft position from the onboard GPS receiver is reported back on the S band telemetry link
- The orbit is estimated and fitted into a mathematical model
- The predicted tracking angles for each pass are pre-computed and stored in the earth station control computer
- During a pass, the predicted tracking angles are actuated using a time reference from an earth station GPS receiver

15

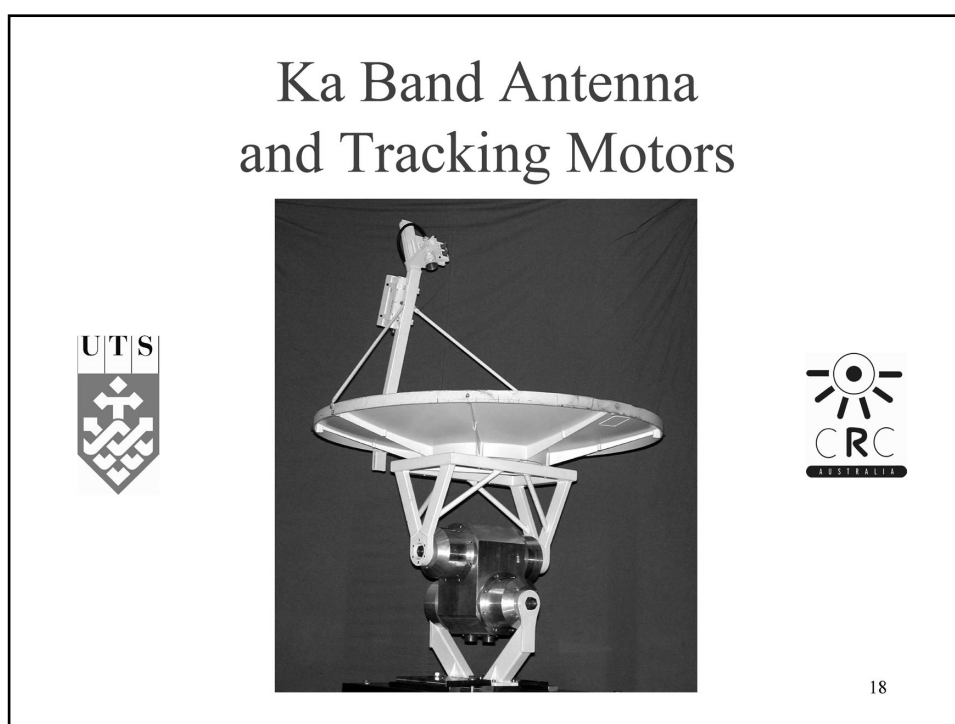
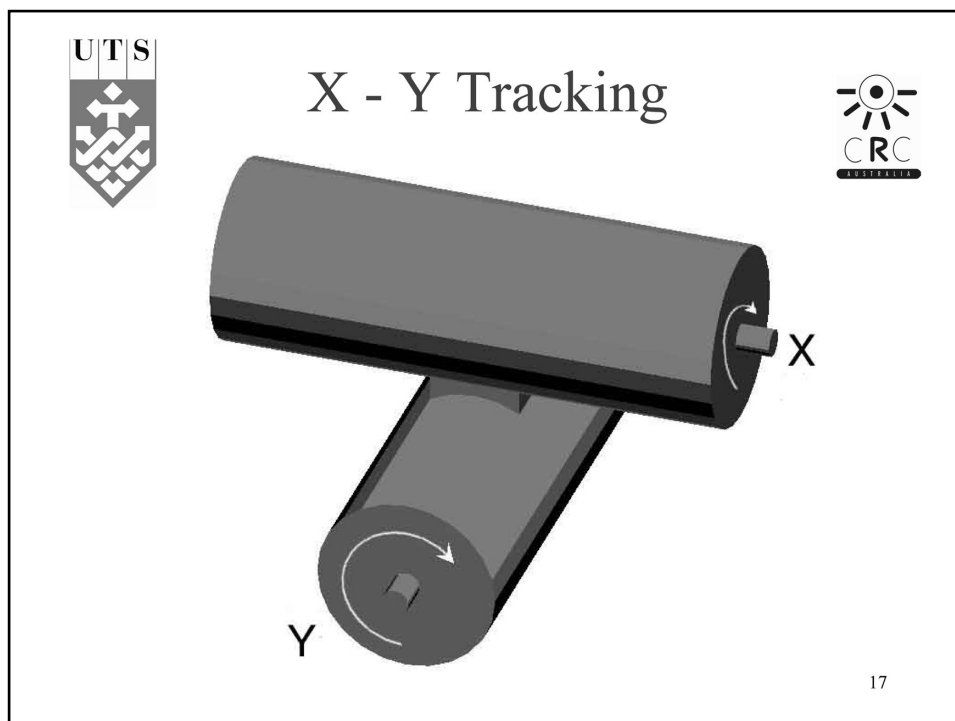


X-Y Tracking Pedestal



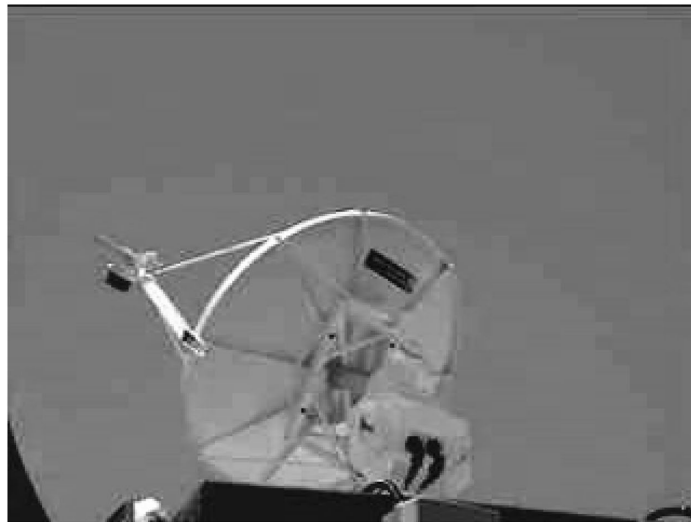
- **Azimuth / Elevation Pedestals**
 - >6 degrees/s tracking requirement
 - costly
 - azimuth rate problem for directly overhead passes
- **X - Y Tracking Pedestal**
 - “Off the shelf components”
 - Two axis AC brushless servo mount
 - Full hemispherical tracking
 - Lower tracking rate requirements than Az/El pedestal

16





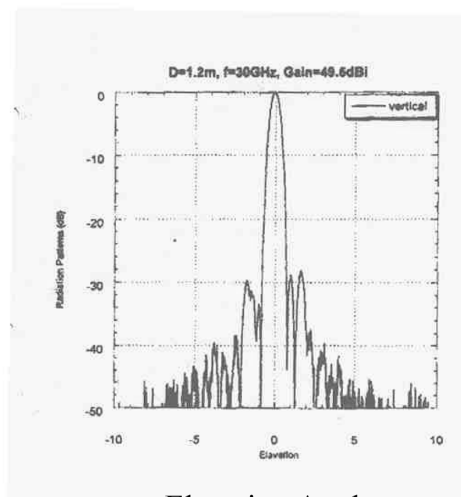
Ka Band Antenna and Tracking Motors



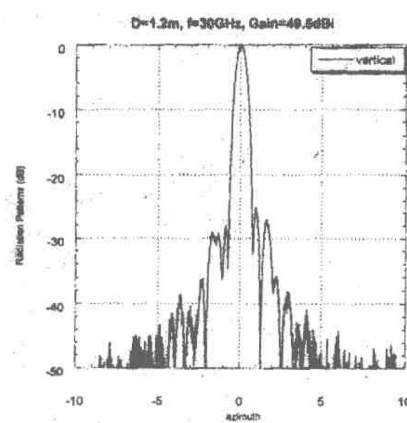
19



Transmit Antenna Gain Pattern

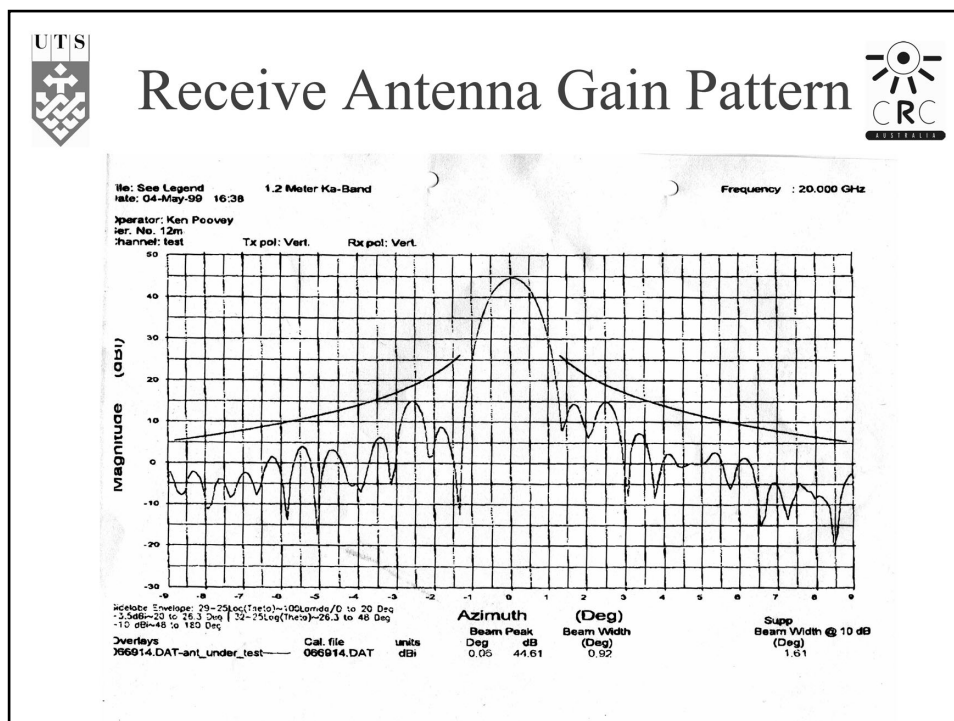


Elevation Angle



Azimuth Angle

20



UTS

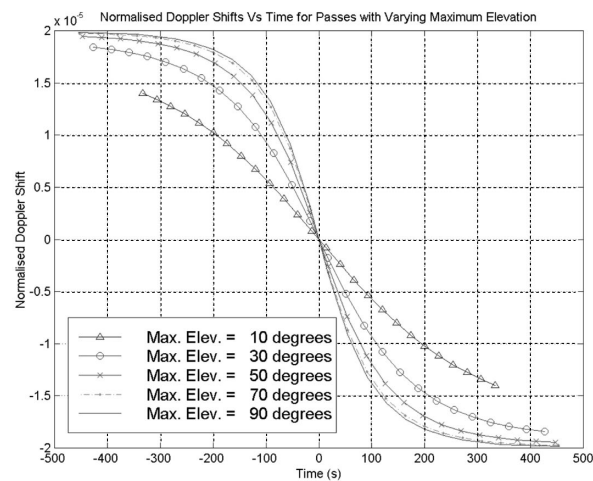
Frequency Tracking

CRC AUSTRALIA

- Maximum Doppler shifts
 - Uplink: ± 662.1 kHz
 - Downlink: ± 441.4 kHz
- Slow local oscillator frequency drifts in the satellite and earth stations
- Rapid acquisition extremely accurate frequency estimation algorithms
- Doppler shifts are removed with small residual error for signals at the inputs to the satellite and earth station modems
- ± 2 MHz range of uplink and downlink Doppler correction

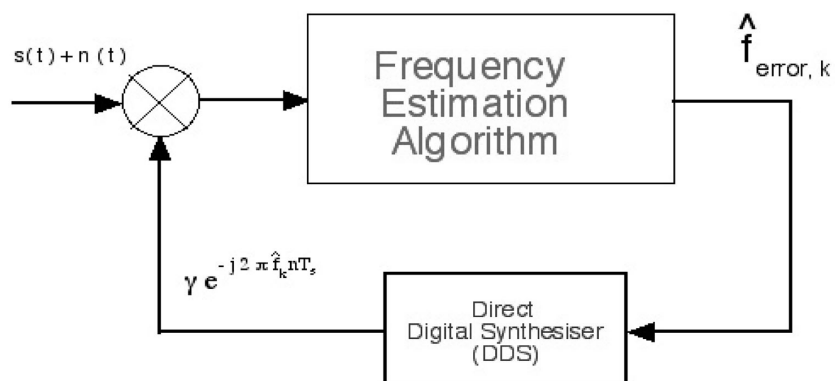
22

Doppler Shift (Normalised Curve for 800 km Orbit)



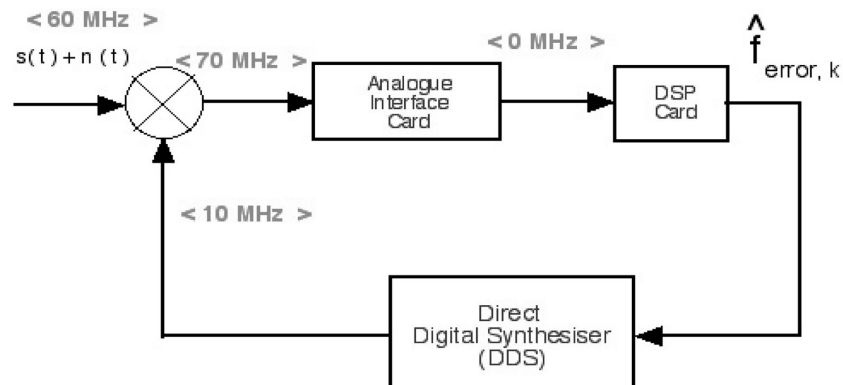
23

Frequency Estimation Conceptual Block Diagram



24

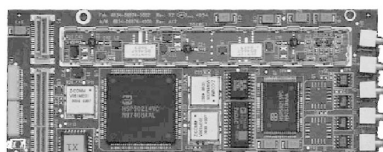
Frequency Tracking Implementation Block Diagram



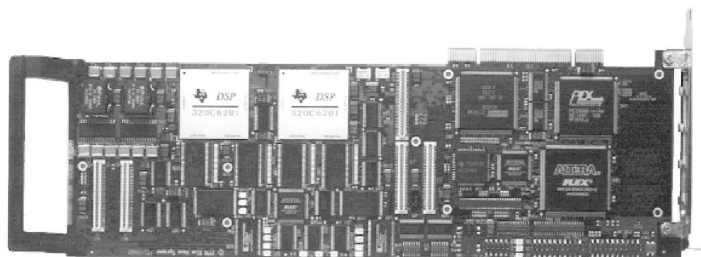
25

Blue Wave SystemsTM Analogue Interface Card and DSP Card

Analogue
Interface
Card



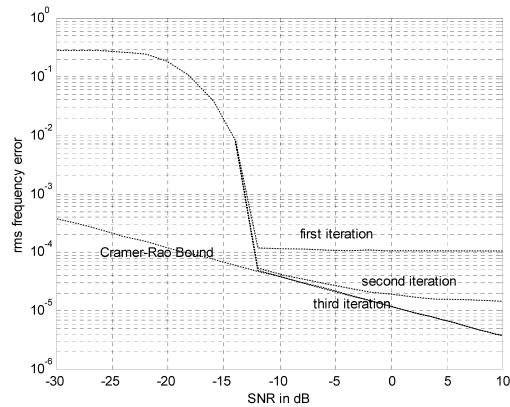
DSP
Card



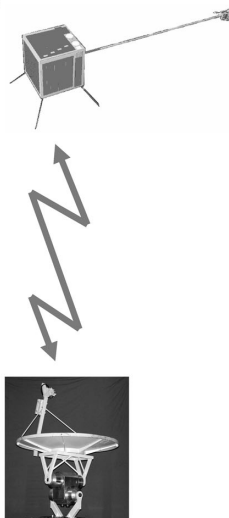
26

Frequency Estimation Algorithm Performance

- Downlink beacon signal frequency estimation algorithm
- Low computational complexity (real time implementation)
- Low signal to noise ratio threshold
- (-12 dB)
- frequency estimation error is only 0.0633 dB above the Cramer-Rao Lower Bound



27



Ka band Earth Station Installation at the UTS Kuring-gai Campus

28

Pedestal Installation



29

Dish Installation



30

Ka band Dish Antenna



31

Precision Site Survey

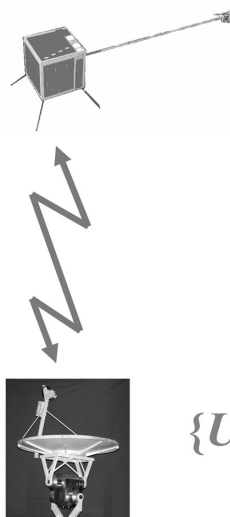


32

Ka band Antenna on Kuring-gai Campus Roof-top



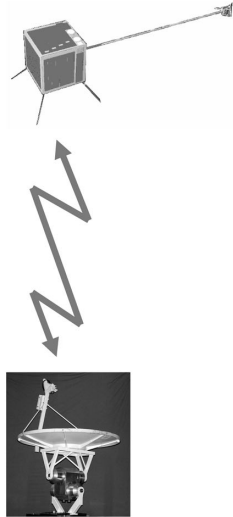
33



FedSat Ka band Transponder and Earth Station Experimental Program 2003-2005 {*UTS, CSIRO-TIP, Univ of SA* }

34

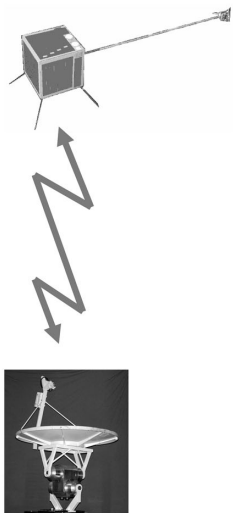
Spatial and Frequency Tracking Experiments



- Beacon mode spatial and frequency tracking
 - Open loop spatial tracking
 - Frequency tracking
 - Open loop tracking
 - Closed loop tracking using the frequency estimation algorithm
 - Hybrid open loop (orbit prediction) and closed loop (signal tracking)

35

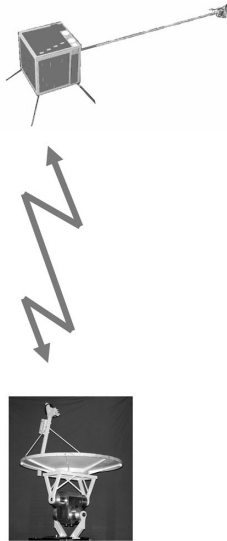
Spatial and Frequency Tracking Experiments (Continued)



- Bent pipe repeater mode
 - Open loop spatial tracking
 - Frequency tracking
 - Uplink Doppler frequency shift local oscillator pre-compensation
 - Downlink
 - Open loop tracking using the orbital model
 - Closed loop tracking using the frequency estimation algorithm
 - Hybrid Techniques

36

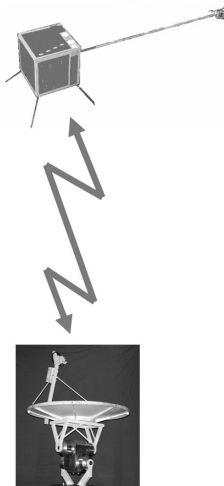
Bent Pipe Link BER Estimation



- Digital Data is transmitted through the FedSat Ka band transponder in bent pipe mode
- The bit error rate (BER) is monitored
- Weather conditions are monitored
- The Ka band channel reliability is statistically characterised
- Sources of BER degradation are identified


37

20 GHz Atmospheric Attenuation Statistical Characterisation




- The Ka band transponder is in beacon mode
- The downlink signal strength is monitored
- The free space loss and spacecraft antenna pointing error gain reduction are computed
- The 20 GHz atmospheric attenuation is statistically characterised
- Models for 20 GHz atmospheric attenuation from a LEO satellite are developed

38




Applications of the Research

Large International Earth Station Market




Low Earth Orbit	Geostationary Orbit
<ul style="list-style-type: none"> -Scientific Satellites -International Space Station -Imaging Satellites <ul style="list-style-type: none"> - Surveillance - Earth Resources - Law Enforcement -Defence Communications -Data Collection -Commercial Communications 	<ul style="list-style-type: none"> -Japanese WINDS Satellite -Japanese Quasi-Zenith Satellite -Commercial Ka band Communications Satellites <ul style="list-style-type: none"> - Broadband Internet Access for Business - Provision of Rural Communication Services


39




Developed Technologies for

Large International Earth Station Market





- Satellite Systems Design
- Systems Engineering
- Ka band Electronics
- Communication System Electronics
- Frequency Tracking
- Spatial Tracking (Antenna Steering)
- Modem and Codec Design
- Digital Signal Processing
- DSP Processor Software
- Earth Station Software



40



International Collaboration

- CRL Japan
- NASDA Japan
- NASA (John Glenn Research Centre) USA
- JPL USA
- ETRI Korea
- NTU and DSO Singapore
- ESA Europe
- Astrium Germany

41



The Future



≥ **Commercialisation** of Developed Technologies
 ≥ **CRCSS** (FedSat Experiments, FedSat II, FedSat III)

≥ **DSP Applications** Development (Modems, Codecs, and other functions)

- New Algorithms and Approaches
- DSP Processors
- Field Programmable Gate Arrays (FPGA)
- Applications Specific Integrated Circuits (ASIC)

≥ **Advanced Earth Station Development**

- Higher Data Rates
- Miniaturization
- Low Power
- Specific Requirements

42



FedSat gets Australian Federal Government Attention



Federal Minister for Science the Hon Peter McGauran, MP and UTS Engineering Associate Professor Sam Reisenfeld.

WHALE ECOLOGY OBSERVATION SATELLITE SYSTEM

Tomonao Hayashi
Chiba Institute of Technology
2-17-1, Tsudanuma, Narashino, Chiba275-0016, Japan

Abstract

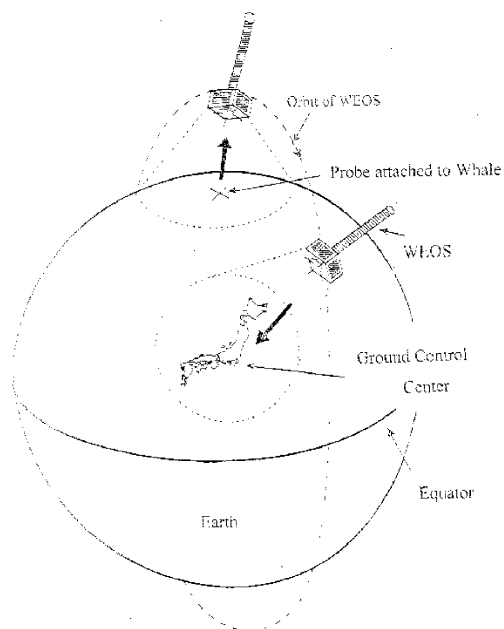
A Whale ecology observation satellite (WEOS) was successfully launched on 14th December 2002 by H-2A rocket as one of the piggyback satellites into a polar circular orbit (774km x 812km) from Tanegashima Space Center. The objective of the WEOS is to collect the data from probes, attached to whales for studying the ecology of whales globally. Another objective in engineering aspect is to develop the WEOS with sophisticated functions cost-effectively based on our philosophy. This paper describes the WEOS system, our cost reduction means, and its results and the in-orbit results.

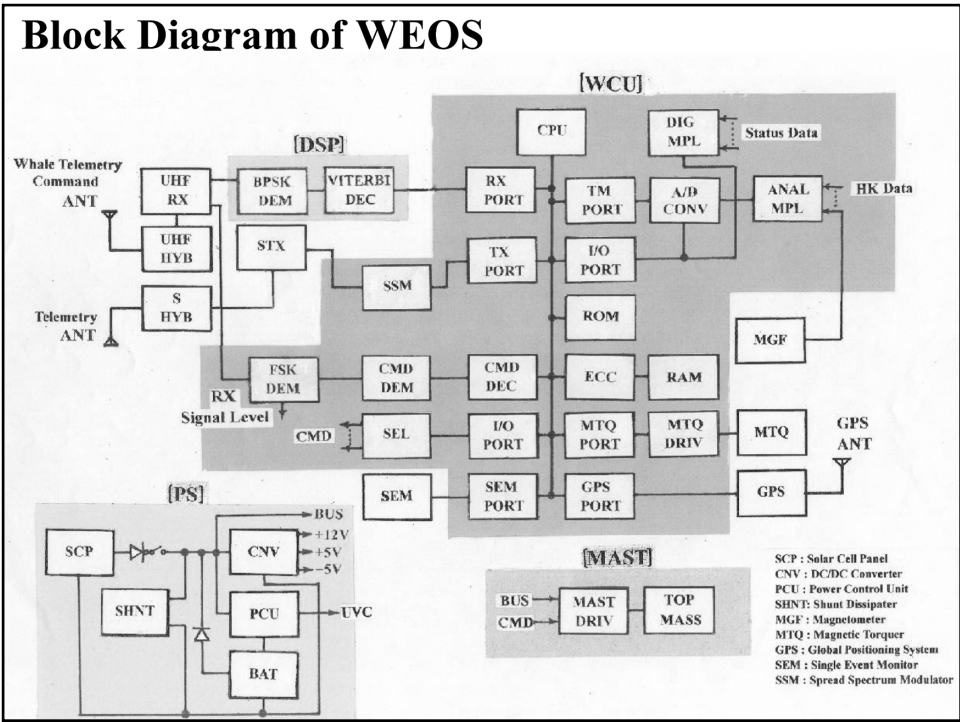
Gravity gradient control technique with autonomous stabilization system is applied to the WEOS for pointing the communications antennas toward the earth, and the a GPS antenna toward the zenith. In a probe attached to a whale are installed sensors of position (GPS), temperature of the sea, and diving depth. The data of the sensors are stored in a memory in the probe. When the whale surfaces for breathing, sensor data in the memory are transmitted to the WEOS. The probe data received by the WEOS are once stored in a central processing unit (WCU) together with on-board GPS and house keeping (HK) data. Signal is sent to the satellite to retrieve the collected data.

WHALE ECOLOGY OBSERVATION SATELLITE SYSTEM

Tomonao HAYASHI
Chiba Institute of Technology

Plan of the System





Communications

Communications	Signal	Frequency	Code & Bit Rate	Note
Whale Probe → Satellite	Telemetry	401 MHz	PCM (NRZ-S)-BPSK Bit Rate: 300bps Symb. Rate: 600bps	Earth → Space
Satellite → Ground Station	Telemetry	2285 MHz	PCM(NRZ-S)-BPSK 1200bps	Space → Earth
Ground Station → Satellite	Command	401 MHz	PCM(Bi φ)-FSK 1200 bps	Earth → Space

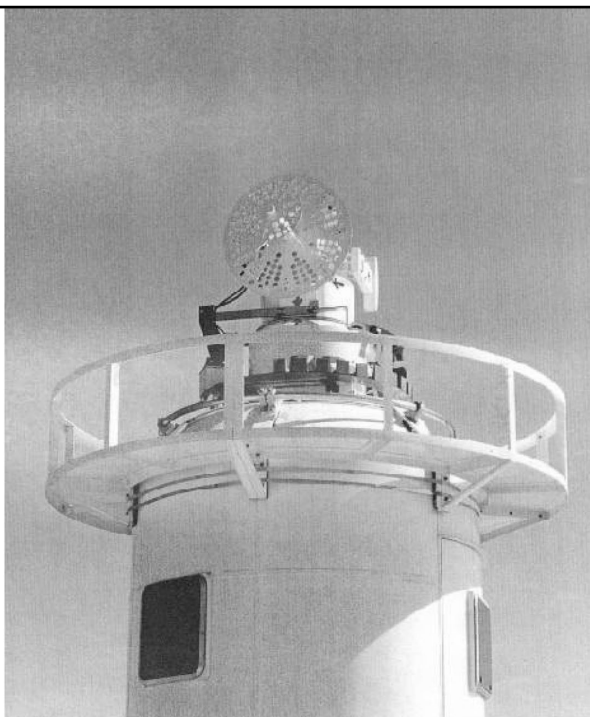
Weight and Power Consumption of Onboard Instruments

Subsystem	Weight [kg]	Power Consumption [W]
Power	10.9	0.2
Communications	2.1	4.1
Data Processing	1.9	4.1
Attitude Control	6.3	1.0
Measurements	1.0	0.5
Structure	12.2	0
Balance Weight	3.0	0
Harness	5.0	0
Total	42.4	9.9

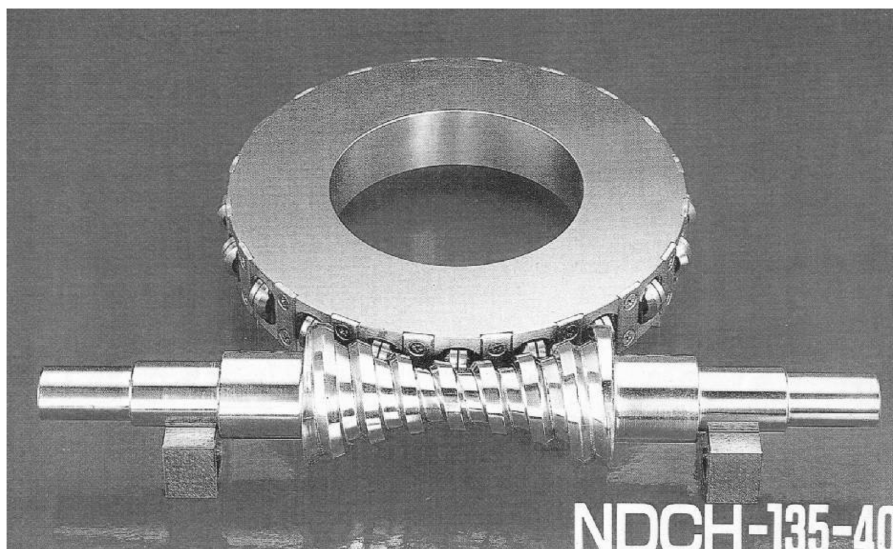
Receiving Antenna in S- Band at Chiba Institute of Technology



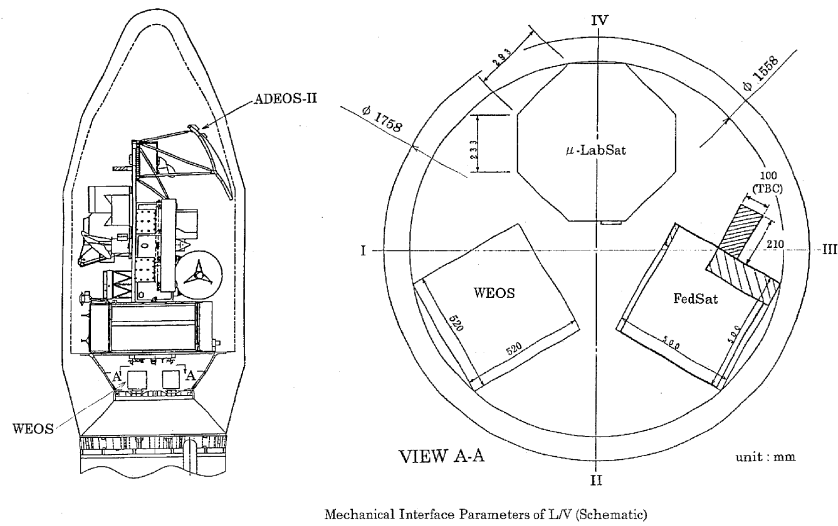
**Command
Antenna in
UHF
at Chiba
Institute of
Technology**



**Non Back-lash
Driving System for
Antenna**



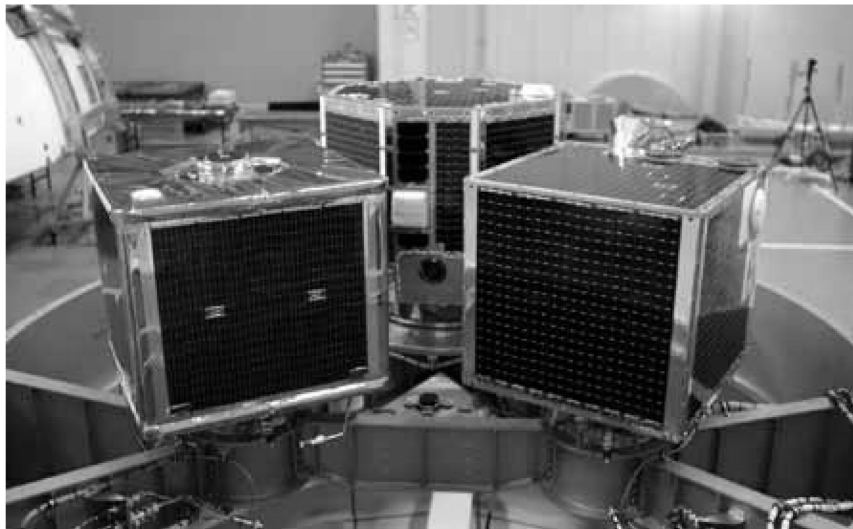
Piggy Back Satellites of H2A-4 (1)



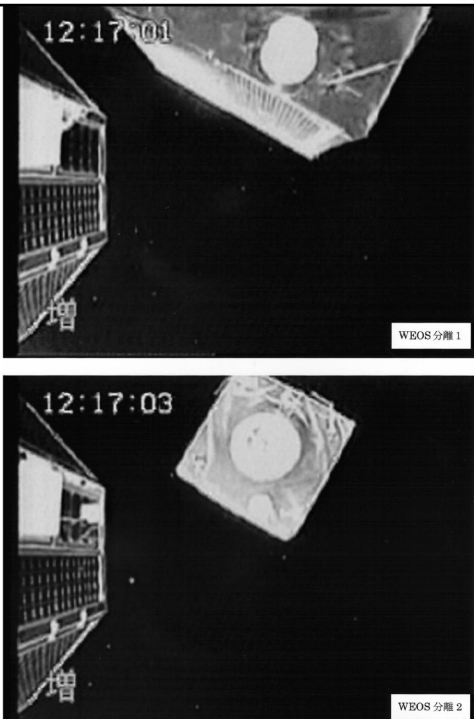
Piggy Back Satellites of H2A-4

(2)

種子島 H2Aピギーバック衛星



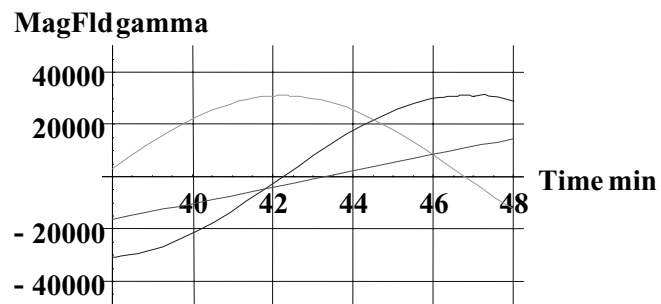
**Separation
of WEOS
from H2A-4**



Gravity Gradient Stabilization (1)

Dec.14-	Tracking Test
Jan.3-Jan.16	Performance Check Spin Reduced from 0.35rpm to 0.05 rpm by Magnetic Torquer Control
Jan.17	Sent Command Signal for Mast Extension
Jan.24	Attained Gravity Gradient Stabilization

Gravity Gradient Stabilization (2)



$$GX = 31000 \sin \frac{2\pi}{18} (t - 42.25)$$

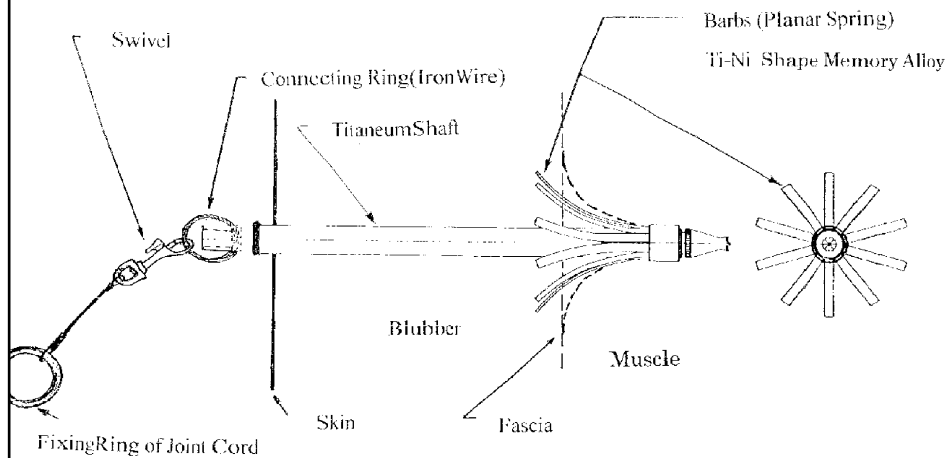
$$GY = 31000 \cos \frac{2\pi}{18} (t - 42.25)$$

$$GZ = 50000 \sin \frac{2\pi}{100} (t - 43.3)$$

Sensors on the Probe

- Position (GPS Receiver)
- Diving Depth (Pressure Gauge)
- Sea Temperature
(Thermometer)
- Acoustic Signal (Microphone)
- Velocity (Tachometer)
- etc

Concept of the Pin for Attachment



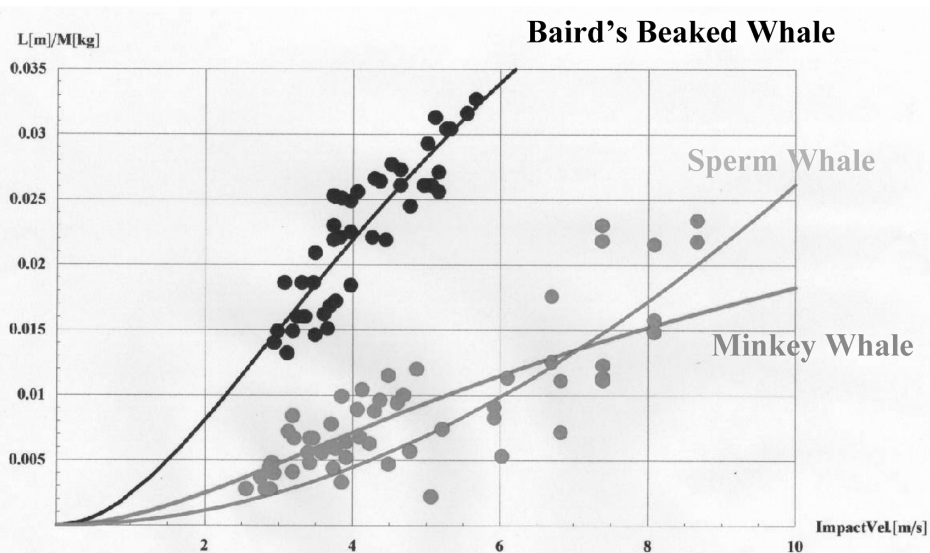
Pin, Weight, and Air-gun for Attachment



Measurement of the Resistance of Blubber



Results of the Drop Test



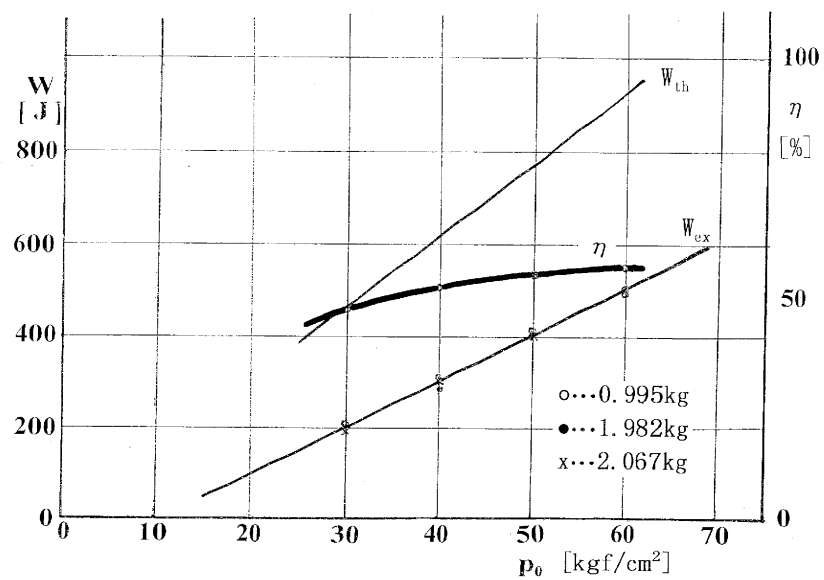
List of Resistive Parameters

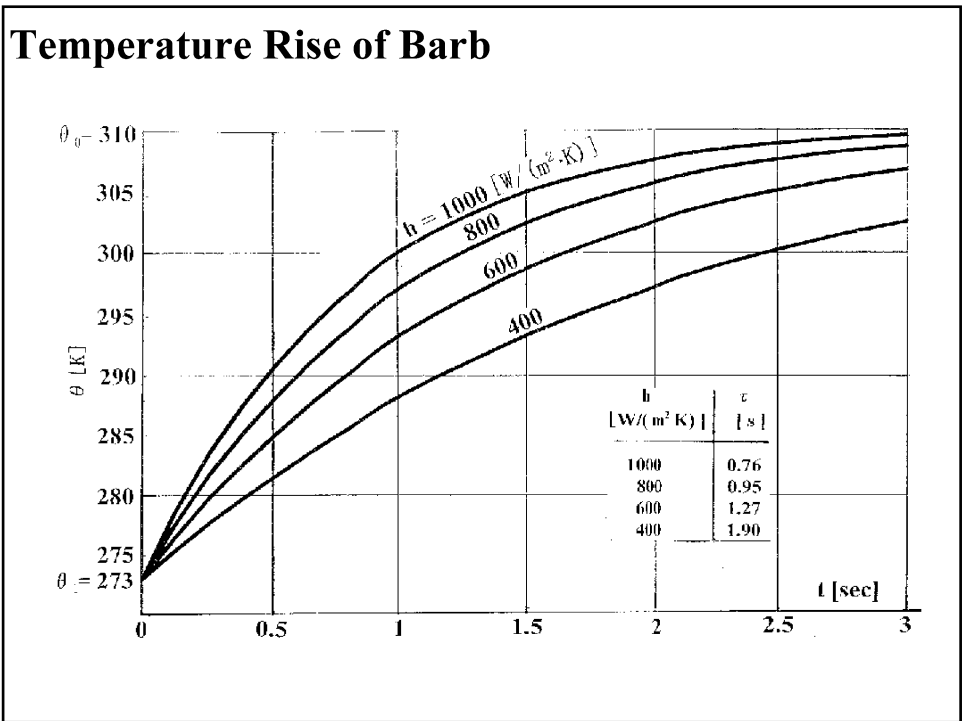
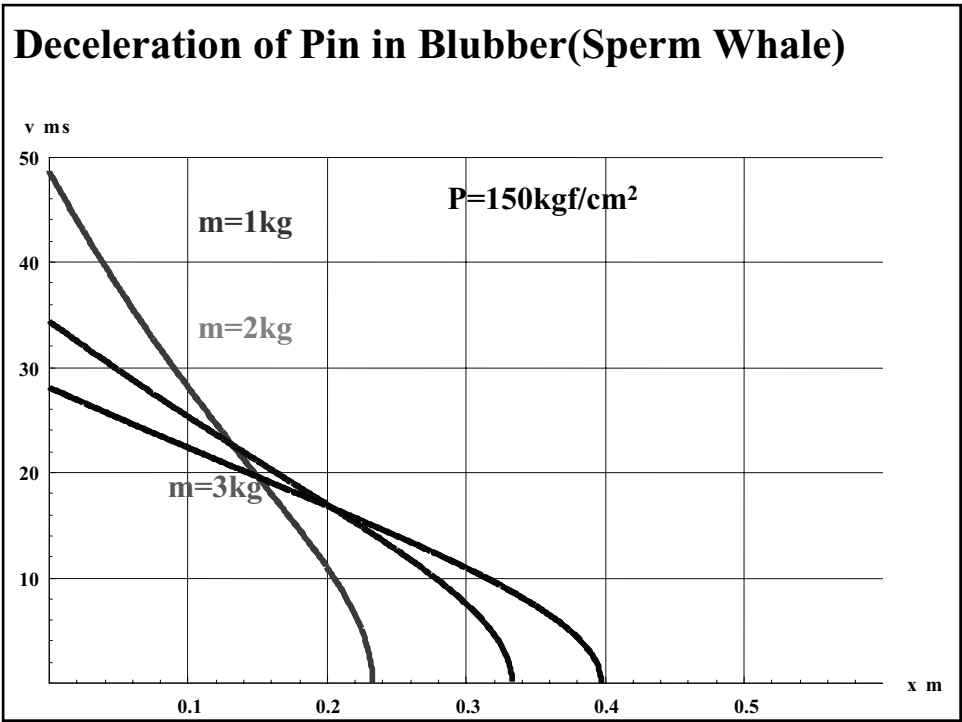
$$m \frac{dv}{dt} = -\alpha (v^2 + \lambda^2)$$

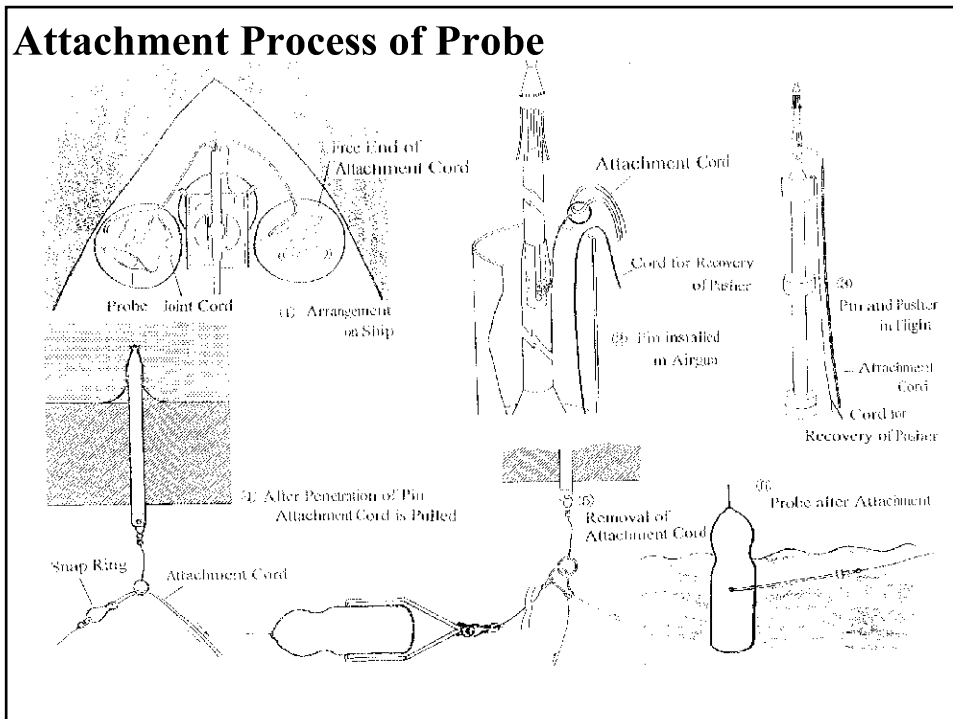
$$\frac{L}{m} = \frac{1}{2\alpha} \ln \left\{ 1 + \left(\frac{v}{\lambda} \right)^2 \right\}$$

	α	λ
Minkey Whale	63.6	3.2
Baird' s Beaked Whale	25.1	2.83
Sperm Whale	4.28	19.35

Capability of Air-gun and its Efficiency







Summary

- ***Whale Ecology Observation Satellite (WEOS) was successfully launched by H2A-4 rocket as one of the piggy back payloads from Tanegashima Space Center into a planned orbit on Dec. 14. 2002.**
- ***The attitude of WEOS established its gravity gradient stabilization mode for pointing the antennas to the earth in the end of Jan. 2003.**
- ***Tracking and control operation along with various tests are continued satisfactorily through a ground station at the Chiba Institute of Technology.**
- ***Attachment of probes to whales will be conducted in the near future at Muroto or Ogasawara in Japan.**

Overview and status of Micro LabSat

Takeshi Ohtsubo Nobuhiro Takahashi

Toshiyuki Nakamura Atsushi Noda Hidekazu Hashimoto

Micro Space Systems Laboratory

National Space Development Agency of Japan (NASDA)

Tsukuba Space Center, 2-1-1 SENGUN, TSUKUBA-shi, IBARAKI, 305-8505, JAPAN

Shinichi Kimura

Communication Research Laboratory

4-2-1 Nukui-kitamachi Koganei Tokyo 184-8795, Japan

Introduction

Micro LabSat is a 50kg-class, spin-type micro satellite, fabricated by the Micro Space Systems Laboratory, as in-house project. Micro LabSat was launched as a piggyback satellite of ADEOS-II by H-IIA rocket No.4 on 14 Dec 2002, with FedSat and WEOS.

The experiments of MicroLabSat are as follows.

- (1) Bus system demonstration of 50kg-class micro satellite (NASDA)
- (2) New satellite separation mechanism (NASDA)
- (3) The demonstration of remote inspection technology
(CRL, NAL, University of Tokyo, NASDA)

In this paper, we introduce overview and status of Micro LabSat.

System Design , Development and Test

The concepts of system design of Micro LabSat are simple, electrical power saving, and using of COTS. These concepts resulted from few resource of mass and electrical power, and the aim of low cost. Micro LabSat had been developed by the members of our laboratory thorough all phases, including the system designs, components design, software design and coding, system integration, system tests, environmental tests, and launch operation.

Thus experience “full course menu” will enable to contribute practically to other projects.

Operation system of Micro LabSat

Micro Satellite Control Center is located in Tsukuba Space Center, Japan. There are 3 Tracking and Communication Stations in NASDA. They are located in Katsuura, Masuda, and Okinawa.

The satellite operation system for Micro LabSat consists of 5 personal computers working under Windows NT4.0 and several client computers. All computers are connected with TCP/IP network. 2 gate computers are connecting to NASDA ground network for sending command to the satellite and receiving telemetry from the satellite. 3 server machines are connecting to the gate computers for the server service to the client computers. The gate computers and the server computers are redundant. Command sending software and Telemetry monitoring software are working on client computers.

Status of Micro LabSat operation

After 2074 seconds from lift off, Micro LabSat got signal from H-IIA and satellite bus ignition was turn-on. Micro LabSat started auto sequence from its onboard computer. In order of sequence, Micro LabSat separated from H-IIA by new separation mechanism on the satellite which is the first mission of the satellite.

During the critical and initial checkout stage, the satellite bus system and satellite operation system function normally. All missions in spin mode were completed with successful. Also 3-Axis stabilization experiment was performed with successful.
Remote inspection experiment will be performed in March and May.

Overview and Status of Micro LabSat



Micro Space Systems Laboratory
Advanced Mission Research Center
Office of Research and Development



Micro LabSat




Launch

- Micro LabSat is a 50kg, spin-type micro satellite, fabricated by NASDA's young engineers.
- It was launched as a piggyback satellite of Advanced Earth Observing Satellite-II (ADEOS-II) by H-IIA rocket No.4 on 14 Dec 2002, with FedSat and WEOS.

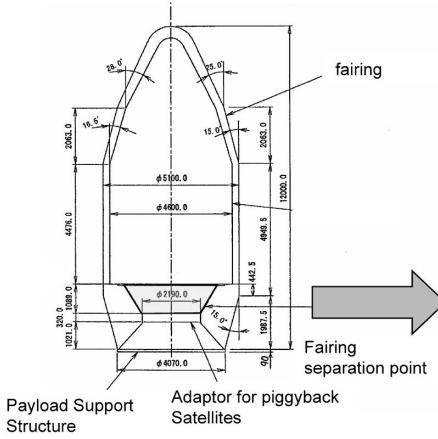


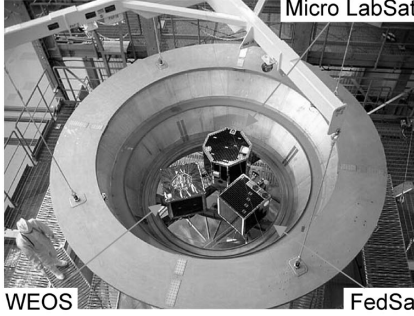
H-IIA No.4

Micro LabSat


NASDA
NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

Launch configuration






Inside of ADEOS-II PAF

Micro Space Systems Laboratory

2

Micro LabSat


NASDA
NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

Main objectives

■ **Main objectives**

1. To achieve a low cost bus and a short period of development
2. To offer a chance of realizing challenging missions
3. Hands- on training of engineers

■ **Experiments**

1. Bus system demonstration of 50kg-class micro satellite
2. New satellite separation mechanisms
3. Demonstration of remote inspection technology

Micro Space Systems Laboratory

3

Experiment #1 (Bus system Demonstration of 50kg-class micro satellite)

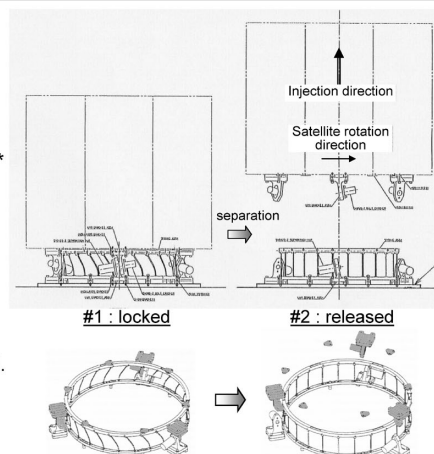
- Reliable and highly functional onboard computer
 - 32bit CPU, multi task processing, three redundancy
- Majority decision method (comparative computation)
 - Necessary to use commercial devices (e.g. CPU, SRAM, FPGA)
- Three-axis stabilization of 50kg-class satellite
 - First application to NASDA's satellite of this class
- Power control by peak power tracking (PPT)
 - First application to Japanese satellite
- Application commercial devices
 - e.g. electronic devices, battery cell, oscillatory heat pipe,

Experiment #2 (New satellite separation mechanisms)

- Using resilient bow springs
- Micro LabSat is released with rotation from rocket
- This separation mechanism will be used as the relay satellite of SELENE*

*SELENE : SELEnological and Engineering Explorer
 SELENE is the first Japanese large-scale lunar orbiter.

- #1** : Satellite is attached with the condition where the bow spring assembly is twisted.
- #2** : The restoring force of resilient bow springs enable the satellite to separate and rotate at the same time.



Micro LabSat



Experiment #3 (Demonstration of Remote inspection technology)

- To demonstrate the basic technology of remote inspection and repair service
- Cooperative research project with CRL*, NAL*, University of Tokyo.

1. CMOS camera and highly functional onboard computer used to image processing
2. Image processing technology for navigation and control (fig.1)
3. Motion estimation of free-flying object (fig.2)

CRL : Communications Research Laboratory
 NAL : National Aerospace Laboratory of Japan

fig.1

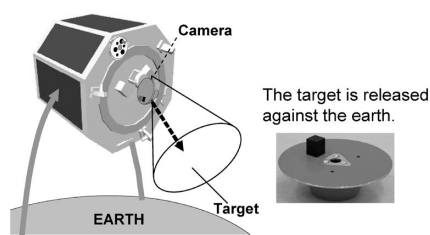
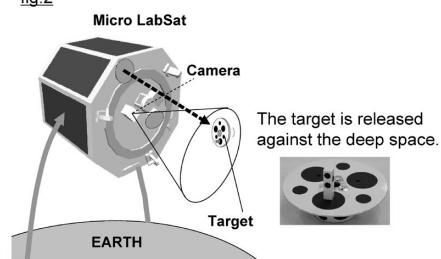


fig.2



Micro Space Systems Laboratory

6

Micro LabSat



Characteristics

Item	Characteristics
Size	$\phi 688 \times 515$ [mm]
Shape	Octagonal prism
Mass	Approx. 54[kg]
Power	55[W] over
Attitude	Spin (at nominal), Three-axis (at mission)
Communications	S-band
Operation span	6 [months] over
Orbit	Sun Synchronous Orbit Altitude: Approx. 800[km] Inclination : Approx.99[deg]
Launch	H-IIA rocket No.4 (piggyback) December 14, 2002



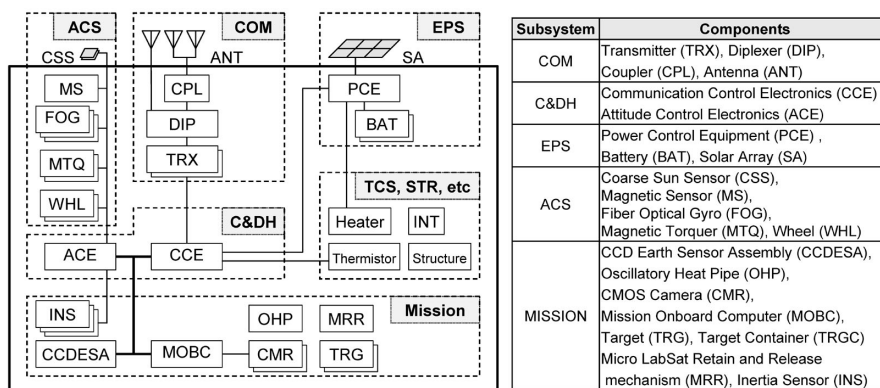
Micro Space Systems Laboratory

7

Micro LabSat



System Block Diagram



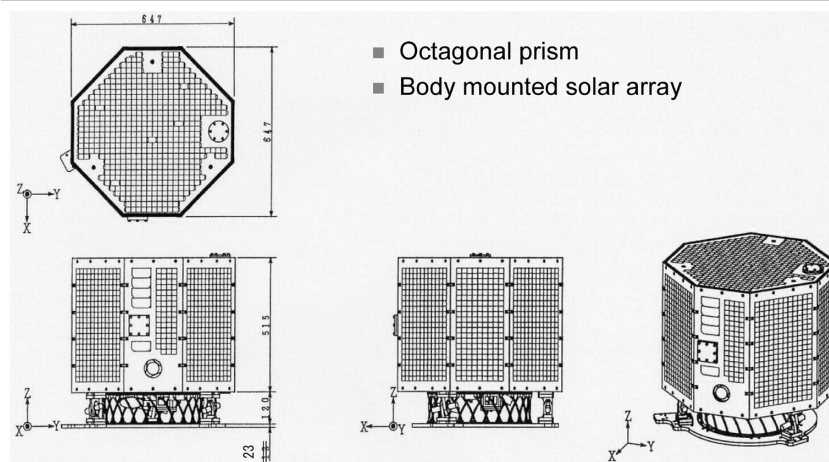
Micro Space Systems Laboratory

8

Micro LabSat




Configuration



Micro Space Systems Laboratory

9

Micro LabSat

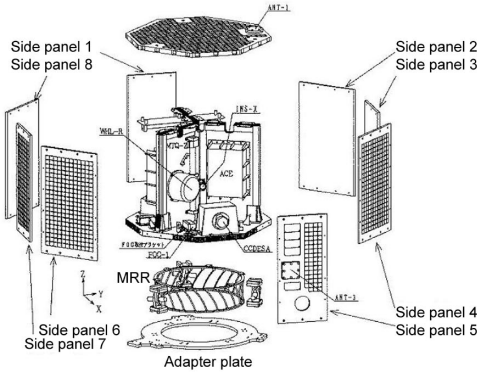


NASDA
NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

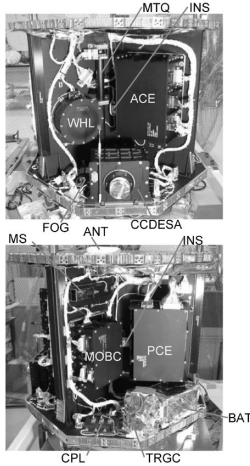
Structure

■ Y-letter shape panel in internal structure

■ Aluminum honeycomb core



Side panel 1
Side panel 8
Side panel 2
Side panel 3
Side panel 4
Side panel 5
Side panel 6
Side panel 7
Adapter plate




MTQ / INS
VHL
ACE
MS
FOG
ANT
CCDESA
INS
MOBC
PCE
BAT
CPL
TRGC

Micro Space Systems Laboratory

10

Micro LabSat



NASDA
NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

Schedule

	1998	1999	2000	2001	2002	2003
Milestone	design review #1	design review #2			Launch	
Design Phase	Preliminary Design	Detailed Design	Design Follow up			
Development & Test	Test of structure model	Test of thermal model				
	Tests of Component		(#1) N.B	System Tests		
Operation				Construction of Operation equipment		Operation

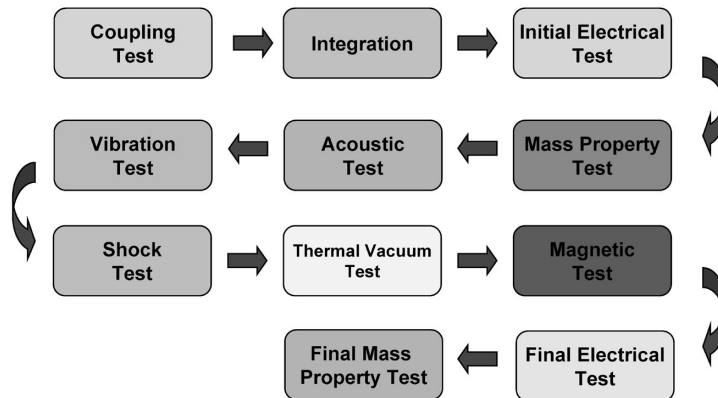
(#1) Doppler Ranging Equipment (DRE) and Laser Ranging Equipment (LRE) were fabricated, and served as payloads on H-IIA test flight #1.

Micro Space Systems Laboratory

11

Flow of system tests

We performed these tests for 8 months.

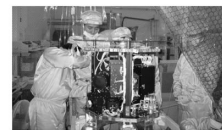


Hand-made Satellite Development (1/2)

- Through Micro LabSat project, members of our Laboratory got opportunities to deal with follows by ourselves;

- **System**

- Analysis and test of structure model
- Analysis and test of thermal model
- System coupling test
- System integration
- System environmental test and electrical test
- Launch operation



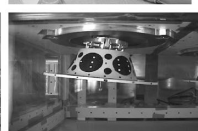
- **Equipment**

- Construction of Several test equipments
(e.g. clean booth, Space chamber, Vibration equipment, etc.)
- Construction of operation system



Hand-made Satellite Development (2/2)

- **Software**
 - Design and coding of onboard software for attitude control, data handling, power control, etc.
- **Component**
 - Basic design of electric circuit of onboard computer
 - Environmental tests of components
 - Design and assembling and test of battery
 - Target release experiment at drop tower
- **Device**
 - Radiation test of commercial device (e.g. CPU, RAM, FPGA, etc.)
 - Screening of commercial battery cells



Operation system (1/5)

- Micro Satellite Control Center is located in Tsukuba Space Center.
- There are 3 Tracking and Communication Stations for Micro LabSat.



Micro Satellite Control Center



Tsukuba Space Center



Tsukuba Space Center (TKSC)

Katsuura Tracking and Communication Station (KTCS)

Masuda Tracking and Communication Station (MTCS)
Tanegashima Space Center (TNSC)

Okinawa Tracking and Communication Station (OTCS)



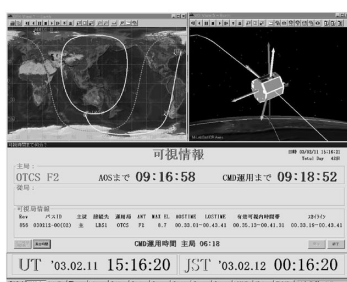
S-band Antennas (OTCS)

Micro LabSat

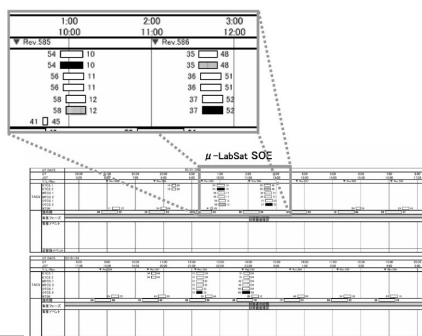


Operation system (2/5)

- Orbit period : Approx. 100 min.
- Inclination : Approx. 99 deg (sun synchronous orbit)
- Operative pass : 4 - 6 pass / day (15 pass)
- Visible duration : Approx. 12min. / pass



Orbit Information of Micro LabSat



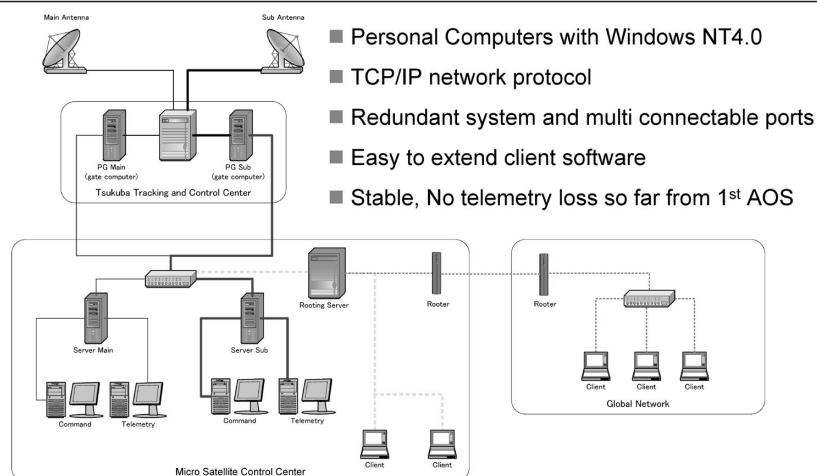
Micro Space Systems Laboratory

16

Micro LabSat



Operation system (3/5)



Micro Space Systems Laboratory

17

Micro LabSat

NASDA
NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

Operation system (4/5)

Micro Space Systems Laboratory

18

Micro LabSat

NASDA
NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

Operation system (5/5)

SOE : Sequence Of Event
SOP : Sequence Of Procedure

Micro Space Systems Laboratory

19

Operation status (1/6)

■ Experiments Status of Micro LabSat

- Bus system demonstration of 50kg-class micro satellite *Work well*
 - ◆ Reliable and highly functional onboard computer *Work well*
 - ◆ Majority decision method (comparative computation) *Work well*
 - ◆ three-axis stabilization of 50kg-class micro satellite *Work well*
 - ◆ Power control by Peak Power Tracking (PPT) *Work well*
 - ◆ Application for commercial devices *Work well*
- New satellite separation mechanism *Complete*
- The demonstration of remote inspection technology
 - ◆ CMOS camera and highly functional onboard computer *Work well*
 - ◆ Image processing for navigation and control *Scheduled in March*
 - ◆ Motion estimation of free-flying objects *Scheduled in May*

Operation status (2/6)

■ The new separation mechanism

- Separation from rocket was successful
- Initial spin rate was 74.5 deg./sec. (plan : 74.5~80.5 deg./sec.)

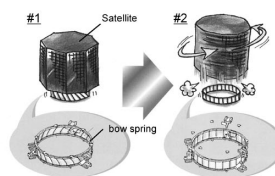


Separation of Micro LabSat
H-IIA onboard camera image

Micro LabSat has a new separation mechanism using resilient bow springs. By this mechanism, Micro LabSat is released with rotation from Rocket.

#1 : Satellite is attached with the condition that bow spring assembly is twisted.

#2 : The restoring force of resilient bow springs enable satellite to provide separation and rotation at the same time.



Micro LabSat


NASDA
 NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

Operation status (3/6)

■ Status of EPS on orbit

	Result (on orbit)	Requirement
Generation Power	About 70W	More than 55W
Max DOD	11 – 13%	Less than 25%
Peak Tracking Efficiency	$95 \pm 1\%$ (Average)	95% (Target)
Conversion Efficiency	More than 93%	More than 90%
BAT TEMP	15 – 20°C	0 – 25°C

Micro Space Systems Laboratory

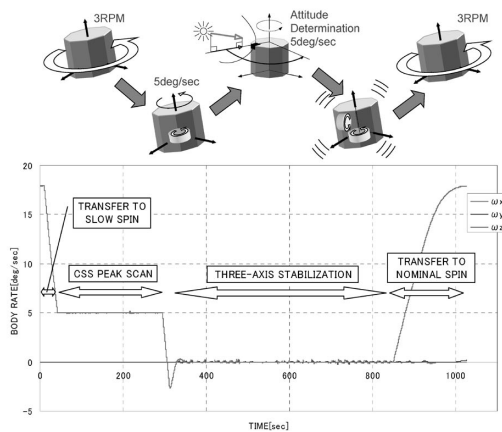
22

Micro LabSat


NASDA
 NATIONAL SPACE DEVELOPMENT AGENCY OF JAPAN

Operation status (4/6)

■ Three-Axis Stabilization Experiment



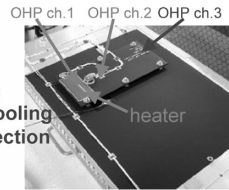
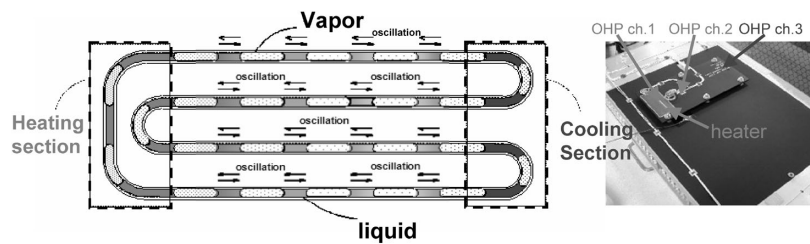
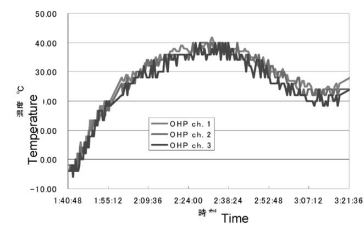
Micro Space Systems Laboratory

23

Operation status (5/6)

■ Oscillatory Heat Pipe

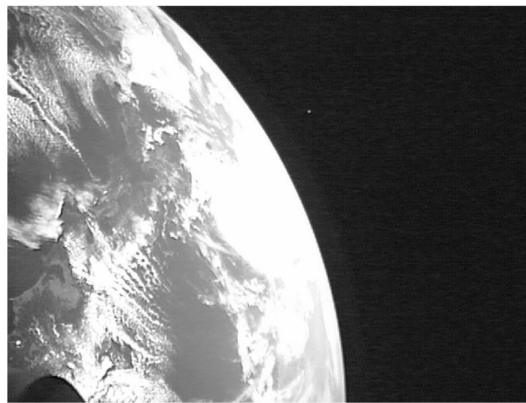
- Advanced thermal control unit
- Lightweight
- Thin, easy to bend
- OHP experiment in the space was successful



Operation status (6/6)

- Earth image captured by CMOS camera developed by CRL*

*CRL : Communications Research Laboratory



Micro LabSat

Conclusions

- Development period : 5 years (1998~2002)
- Total costs : Approx. 4 hundred million yen
- Most of experiments succeeded on orbit.



Start studying Micro LabSat-2 !

*Micro Space Systems Laboratory*

26

Light-satellite for Remote Sensing

Cost Effective Ways for Earth Observation

Soon D. Choi, Ph.D.
Professor Emeritus: KAIST
Chairman: SaTReCi

Abstract

The most efficient means to observe environmental changes on a global scale is to use earth imaging satellites. Images taken by those satellites are transmitted to the ground processing stations to make the raw data useful for practical applications.

However, construction and launching cost of these satellites are so high that it is almost impossible to recover the investment from selling the images through the current practice of image distributions. Hence, in order to make imagery business viable and profitable, the cost for deployment of remote sensing satellite system should be drastically reduced. Thus enough number of satellites can be launched into orbits so that the user demands can be met more timely and less expensively. This would create larger image market.

In this presentation it is shown that all of this is possible with smaller and less sophisticated satellites than currently available systems. Some of such Korean light-satellites are presented together with examples of worldwide trends of remote sensing satellites



Light-satellite for Remote Sensing

Cost Effective Ways for Earth Observation

March 12, 2003

Tokyo, Japan

Soon D. Choi, Ph.D.
Professor Emeritus: KAIST
Chairman: SaTReCi

What is Remote Sensing?

Remote Sensing is defined as
any observation made at a point removed from
the object under observation.

More commonly
it refers to observations of areas of land and
water covering the earth by airplane or satellite.



Why Remote Sensing?

- See Better
- Know Better
- Use Better
- Live Better

Cost for Monitoring Earth

In *“Land Satellite Information in the Next Decade”*
Washington D.C., December 1997
by Ted Nanz, President of SPOT Image, USA

From Paper “Commercial Remote Sensing: A Fad or Killer Products”

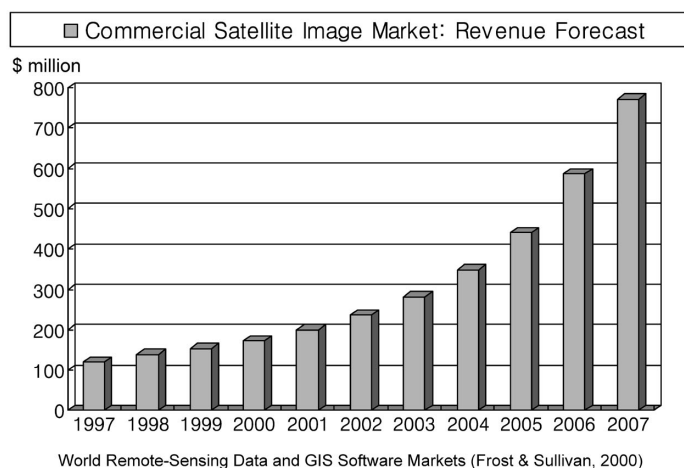
Total Investment of \$ 5 billion for

- Orbview-3
- Earlybird, Quickbird
- SPOT- 4, -5
- EROS series
- IKONOS
- Resource-21

Cost for Monitoring Earth *Cont'd*

- **Building & Launching Cost for those Satellites**
 - approximately \$ 5 billion
 - **Assuming 5 year Operation,**
Average Revenue should be:
 - average depreciation/yr: \$1 billion
 - revenue to cover depreciation: \$ 4 billion/yr (25% profit)
 (280 m USD forecasted in 2003)
 - **Daily sales: 3,653 scenes (\$ 3,000/scene)**
- Is this viable business?**

Current & Future Image Market



Today's Image Market

- **Building and launching an Earth-observation satellite is too expensive and the cost can not be recovered by selling image products in normal business practice.**

(Commercial Remote Sensing Project created by NASA to accelerate "the development of the US remote sensing industry")

- **Data demand will not be met by currently planned commercial satellites (Frost & Sullivan).**

Difficulty of obtaining right data at right time

So: The cost should be drastically reduced, and satellite image market should grow to an economic size

Constraints of Light-sat

➤ Optical System

- Aperture Size
 - 300 mm ϕ for 2~3 m GSD pan (e.g. EROS image)
 - ♦ IKONOS: 700 mm ϕ 1 m pan, 4m ms
 - 100~200 mm ϕ for 10~30 m GSD MS (e.g. KITSAT-3 images)
 - ♦ SPOT 300 mm ϕ 10 m pan, 20 m ms
- MTF
 - 8~15 % obtainable with light-sat



EROS-A1 image of Seoul World-cup Stadium under construction

MTF: 8 %

Resolution: 1.8 m @485 km

Aperture Size: 300 mm

Constraints of Light-sat *Cont'd*

➤ Position and Attitude Knowledge

(due to size of wheels and accuracy of sensors)

- With ground control points (GCPs)
 - 0.5~2 pixel accuracy achievable
- Without GCP
 - 10 arc sec
 - GPS: ~200 m
 - 250 m in theory (practically 1 km)

Limitations with Light-sat

➤ Data Rate, Delivery Time

(due to limited power)

- 10 ~ 30 Mbps in X-band
- 2 ~ 3 passes to receive all image data

◆ Overcoming Low Data Rate

- In normal operation, downloading in 2~3 passes (in a day) may not be a significant shortcoming.
- In emergency, priority downloading can overcome the shortcomings (downloading the scenes of interest first).

Advantages with Light-sat

➤ Constellation Affordable

- Low manufacturing cost
- Low launch cost
- Frequent data update with extra probes
- Fast development
- Use of current technology and improved system reliability

➤ Cost

- \$10 ~ 20 million depending on the resolution, performances, and other requirements.

◆ at least 10 dB lower than current price

Current Light-sats for EO Mission

Item	Mission	Key Features	Launch	Nation
TOPSAT	Earth Observation	2.5 m panchromatic, 15 km swath	2004	U.K.
DMC	Disaster Monitoring	36 m panchromatic, 600 km swath	2004	U.K.
KITSAT-3	Multi-spectral Imaging, technology demo	13.5 m multi-spectral, 50 km swath	1999	Korea
MEISAT (IRIS)	Multi-spectral Imaging	10 m multi-spectral 50 km swath	2004	Korea + Singapore
MACSAT	Earth Observation	2.5 m pan, 5m multi-spectral, 20 km swath	2004	Malaysia + Korea
TiungSAT	Earth Observation	78 m multi-spectral, frame type	2000	Malaysia
FUEGO	Forest Fire Monitoring	12 satellites, 18 m	2005	Spain
HypSeo	Hyper-spectral EO	20 m, 20 km, 12 bits	2000	Italy

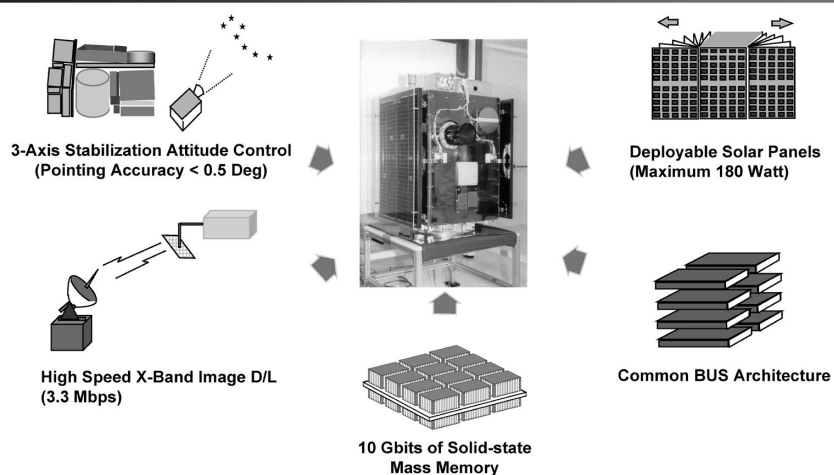
Korean light-satellite: KITSAT-3

- **Low-cost Light-Satellite for Earth Observation**
 - Linear push-broom type Camera
 - PC based ground processing system and mission control center with 13 meter S- & X-band antenna system
- **Developed by Satellite Technology Research Center (SaTReC, KAIST) (1995~1999)**
 - University-based research unit
 - Man-power training
 - Know-how build-up
 - Development of indigenous space technologies for light-satellite



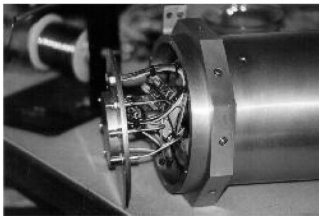
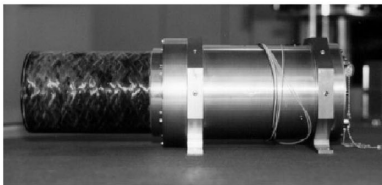
13

KITSAT-3 Features



14

EO Payload of KITSAT-3



- Linear push-broom CCD camera (3456 pixels)
- Spectral bands : 520-620, 620-690, 730-900 nm
- GSD : 13.8 m (@ 730 km)
- Swath-width : 50 km
- Focal length : 560 mm
- Aperture diameter : 100 mm (F# : 5.6)
- MTF : ~ 20 % at 47 cycles/mm
- Mass : 6.5 kg
- Power consumption : 15 Watts

SaTReC*i*

15

KITSAT-3 Images



Airport (Incheon International Airport)

SaTReC*i*

16

KITSAT-3 Images



Volcanic Eruption (Sakurajima Mt, Japan)

SaTRec*i*

17

KITSAT-3 Images

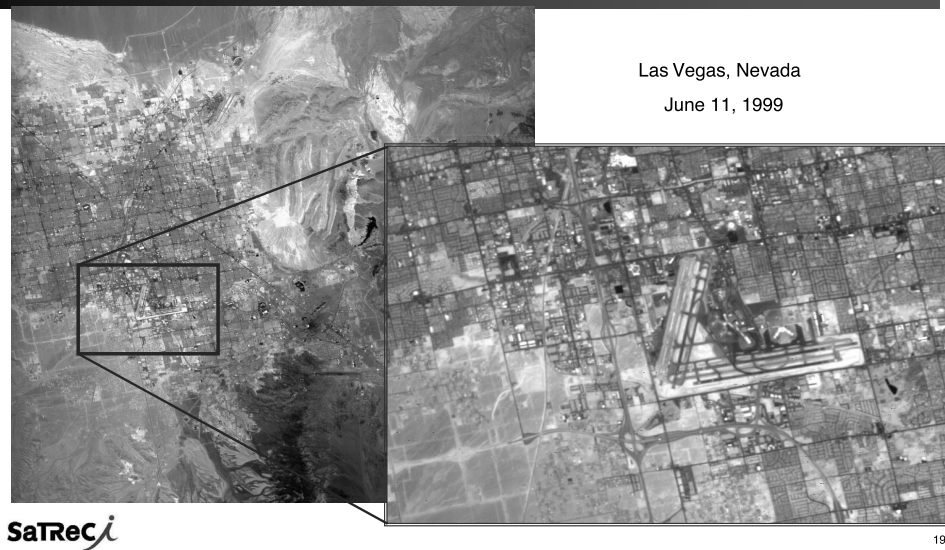


Coastline (South of Saudi Arabia)

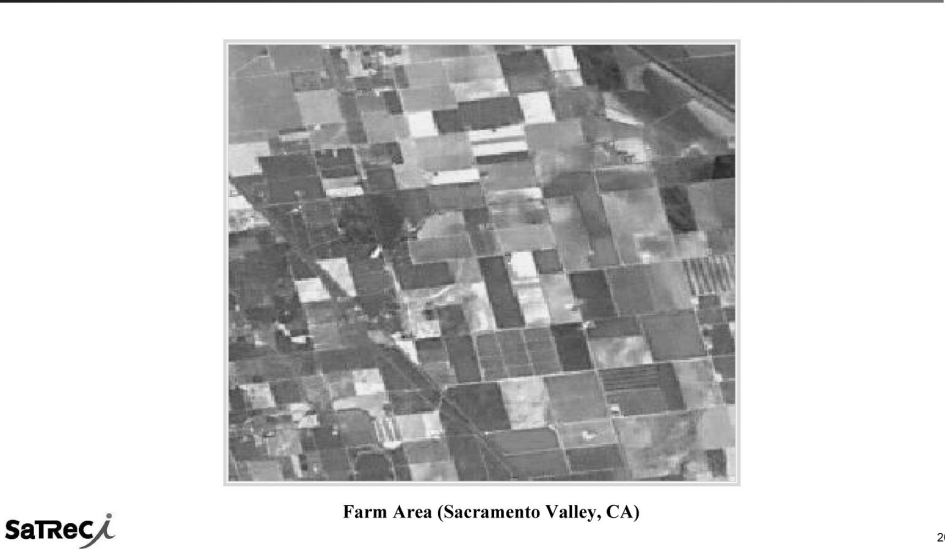
SaTRec*i*

18

KITSAT-3 Images



KITSAT-3 Images



Change Detection using KITSAT-3



June 3, 1999



March 11, 2000

Changi Airport, Singapore

SaTRec*i*

21

Image Fusion (KITSAT-3 & KOMPSAT-1)



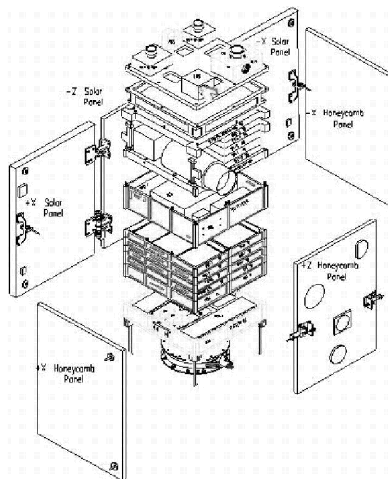
After Image Fusion

KOMPSAT-1/EOC Image (6.6 m GSD)

SaTRec*i*

22

Specifications of KITSAT-3



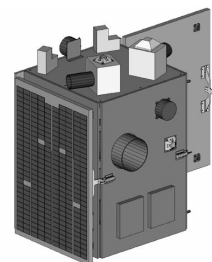
- Launch date May 26, 1999 15:22 (in KST)
- Launcher PSLV-C2 (ISRO)
- Orbit 720 km sun-synchronous
- Mass 110 kg
- Dimension 495 X 604 x 837 (mm)
- Power 180 watt (max)
- Attitude control 3-axis stabilized
- Pointing accuracy < 0.5 Deg
- Frequency bands Uplink 148 MHz
Downlink : 401 MHz, 2.2 GHz & 8.2 GHz
- Common bus architecture
- Main computer 80C960 (32 bit RISC processor)
- Operating system Star-keeper (multi-tasking O/S)

SaTReC*i*

23

MEISAT (Multi-spectral Earth Imaging Sat)

- Push-broom imaging system
- Multi-spectral imaging in 3 bands
- 10 m GSD & 50 km swath-width @ 685 km
- 8 Gbit mass storage with SDRAM devices
- 10 Mbps image data transmission in X-band
- Compact, light weight, low power consumption



SaTReC*i*

24

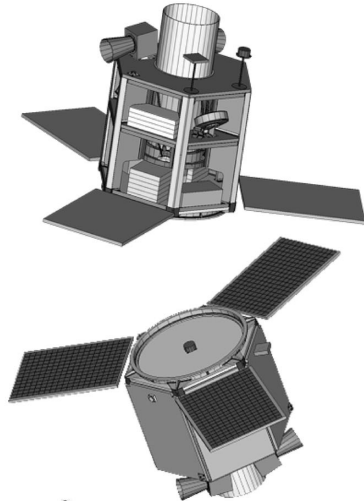
System Specifications of MEISAT

Item	Specification	Remarks
Spectral Bands	G, R, NIR	
Ground Sampling Distance (GSD)	10 m @ nadir	685 km nominal altitude
Swath-width	50 km @ nadir	685 km nominal altitude
Modulation Transfer Function (MTF)	$\geq 15\%$ @ Nyquist freq.	For entire FOV
Signal to Noise Ratio (SNR)	≥ 100	$\rho = 0.25, \theta_z = 65 \text{ deg}$
Aperture Diameter	$\sim 120 \text{ mm}$	
Effective Focal Length	$\sim 600 \text{ mm}$	$f \# = 5$
Number of Active Pixels	5,000	
Gain Control	Programmable	
Quantization	8 bits	
Mass Storage Capacity	8 Gbits	SDRAM
Data Transmission Rate	10 Mbps	X Band, QPSK
Mass	$< 12 \text{ kg}$	
Power Consumption	$< 25 \text{ W}$	Peak consumption

MACSAT (Medium-size Aperture Camera Satellite)

- **High resolution optical camera in a total weight of less than 200 kg spacecraft**
- **MACSAT under joint development by ATSB, Malaysia and SaTReC*i*, Korea**
- **Image applications:
Mapping, Environmental Monitoring, etc.**

Specifications of MACSAT



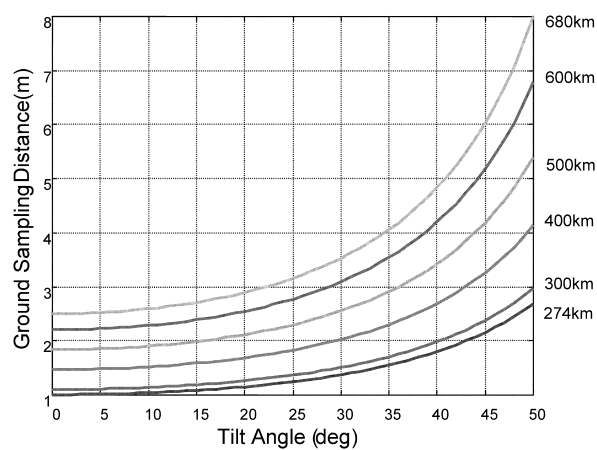
SaTRec*i*

Item	Specification
Mass	< 200 kg
Dimension	Ø 1200 × 1200 (mm)
Incoming Power	240 W @ EOL (GaAs)
GSD / Swath-width	2.5 m (PAN), 5 m (MS) / 20 km (@685 km nadir)
Spectral Bands (MS)	4 (R,G,B,NIR)
Mass Storage	32 Gbits (SDRAM)
Attitude Accuracy	0.2° (3-axis control)
Attitude Knowledge	10 arc sec
TT&C	S-band (9.6 / 38.4 kbps)
Image Transmission	X-band (~30 Mbps)
Mission Life	> 3 years

27

High Resolution Imaging with MACSAT

For Panchromatic Channel



SaTRec*i*

28

Conclusion

- **Light-satellites can not do everything,
but can do many things.
(Space Science, Remote Sensing, Communications)**
- **Light-satellite is the promising solution for earth
observation.**
- **Let's promote New Space Technology for
Light-sat Systems and their Applications.**

Small Satellite for High-bit-rate Data Communication

Hiroyuki OKAMOTO* and Atsushi NAKAJIMA**

* Astro Research Corporation

** National Aerospace Laboratory of Japan

Abstract

Authors are studying the high performance small satellite which has high data rate mobile communication capability. The mission requirements are following:

- i) Using piggy-back launch opportunity for launching
- ii) 6Mbps mobile communication rate using X-band
- iii) High elliptic orbit to increase the communication duration at Tokyo
- iv) High inclination orbit to reduce the blocking due to ground constructions

The orbital requirement is unique, there is no suitable piggy-back launch opportunity by which the satellite can be inserted the required orbit directly. So, this small satellite shall have the orbit change capability, i.e. kick motor.

During this study, from the initial orbit of 400 km altitude circular, the authors chose the following 4 hours orbit.

Semi- major axis	12770 km
Eccentricity	0.47
Inclination	40.0 degree

Using this orbit, the mobile station can access this satellite about 50 minutes from Tokyo. The satellite configuration is shown in this paper.

Small Satellite Symposium 2003
2003.3.12



Small Satellite for High-bit-rate Data Communication

Hiroyuki OKAMOTO

Astro Research Corporation

Atsushi NAKAJIMA

National Aerospace Laboratory

Agenda



- Background
- The Orbit
- The Sattelite

Background

- Medicare in Emergency
 - Relying on the data transmission from the ambulance
 - Early Diagnosis
 - Early Determination of the Hospital
 - Vital Sign, 12 Leads Electrocardiogram, Pupillary Reflex Image
 - Instructions from the Doctor in Hospital
 - Airway Management, Intravenous Line Management, Cardio-Pulmonary Resuscitation


Current Problems from the Field

- Loss of RF Channel
- Shadowing
 - Urban: Building, Power line, etc.
 - Local: Mountains, Forests, etc.
- Phasing

High Elevation Satellite

- Longer AOS at Ceiling
 - Avoid LOS due to the constructions and nature.

Agenda

- Background
-  The Orbit
- The Satellite

Mission Analysis — conditions —

- Conditions are Following:
 - On-board Antenna Diameter ϕ 2000 mm
 - Mission Frequency X-band
 - Ambulance Antenna Diameter ϕ 400 mm
 - Bit-rate 6Mbps
 - Piggy-back Launch

Mission Analysis — orbit analysis—

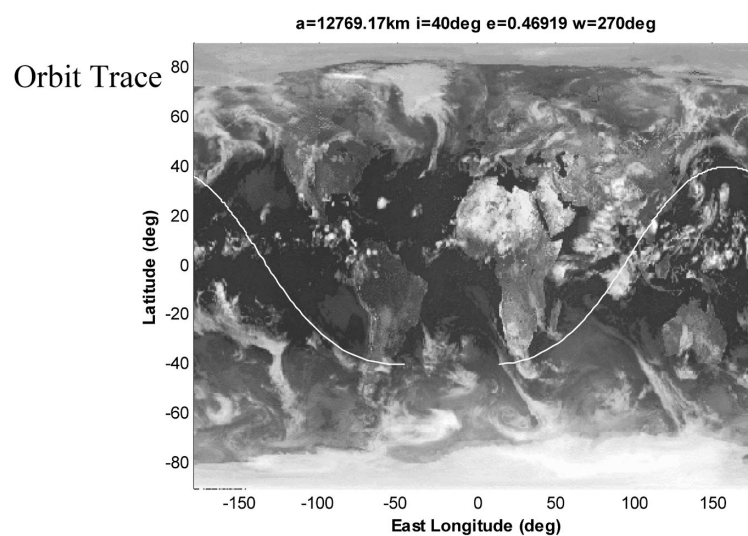
- Analysis Conditions are Following:
- Experiment for the Practical System Development
 - Longer AOS & Higher Elevation from Tokyo
- Practical Satellite: 24 hrs orbit
 - Report from the high elevation satellite committee
- For Piggy-back Launch
 - Orbit Insertion $\Delta V < 1600 \text{ m/s}$ from the Initial Orbit
 - Similar Propellant Mass Fraction of GEO satellite
 - Initial Orbit: GTO or 400km LEO

Mission Analysis — 4 hrs Orbit —

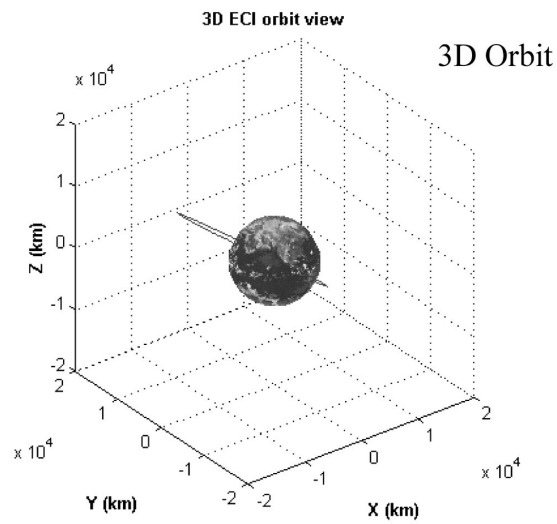
- Orbit Elements

- Semi-major Axis: 12769.17km
- Inclination: 40 deg.
- Ascending Node: 100 deg.
- Angular from Perigee: 270 deg.
- Eccentricity: 0.46919
- Orbit Period: 4 hrs.

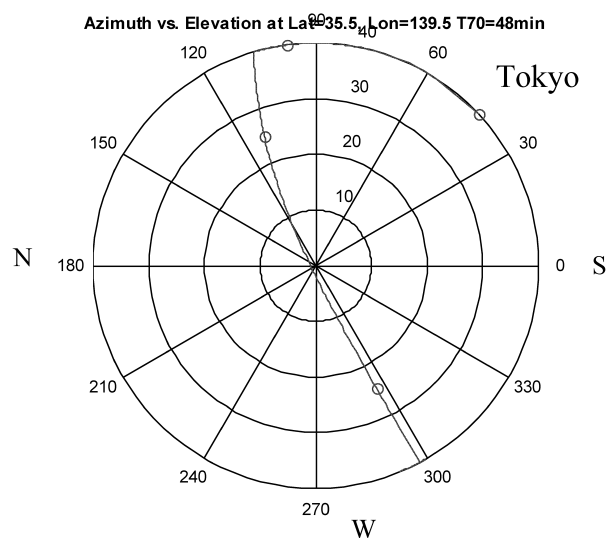
Mission Analysis — 4 hrs orbit —



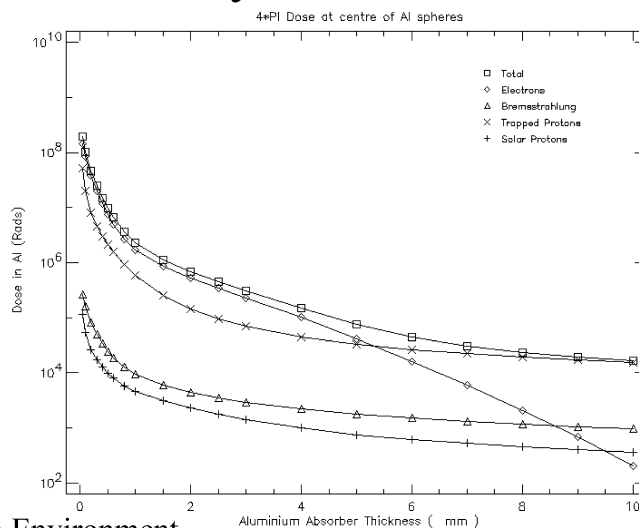
Mission Analysis — 4 hrs orbit —



Mission Analysis — 4 hrs orbit —



Mission Analysis — 4 hrs orbit —




Radiation Environment
(AP-8MIN, AE-8MAX, JPL-91SHIELD-2 results)

Mission Analysis — 4 hrs orbit —

- ΔV for the Orbit Insertion
 - From LEO : 1630m/s
- AOS Duration over 70 deg. Elevation at Tokyo
 - 48 minutes
- Severe Radiation Environment
 - Orbital Average Dose : 78 krad/year@5mmAl
- Comply the Mission Analysis Conditions

Agenda

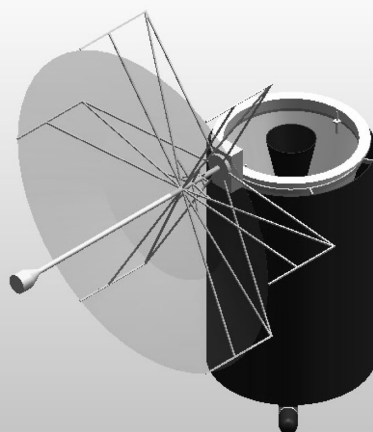
- Background
- The Orbit
-  The Satellite

Satellite Design

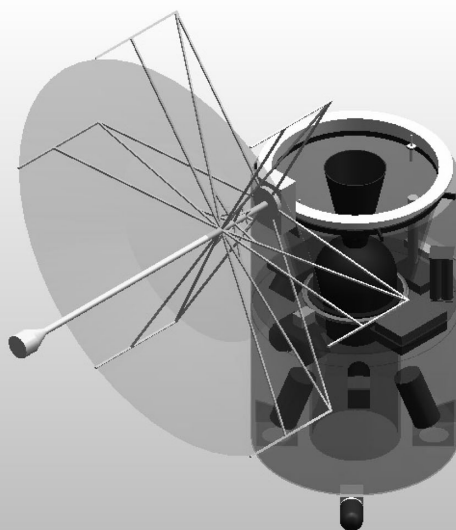
- Off-the-Shelf Components are available
 - Recently, developed for small satellite
 - Power: Multi-Junction Cell, Li-ion Battery
 - Communication: S-band, X-band
 - Attitude Control: Reaction Wheels, Star Tracker, GPS
- Feasibility of Off-the-Shelf Components
 - Essentially Feasible
 - Detail Design is Required (Future Work)

Satellite Design

In Orbit

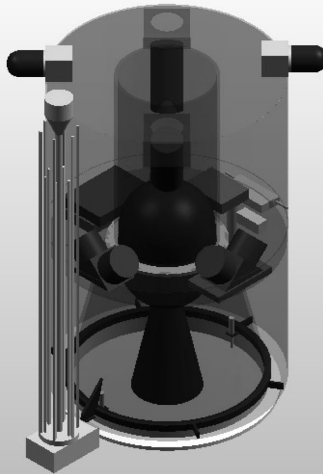


Satellite Design



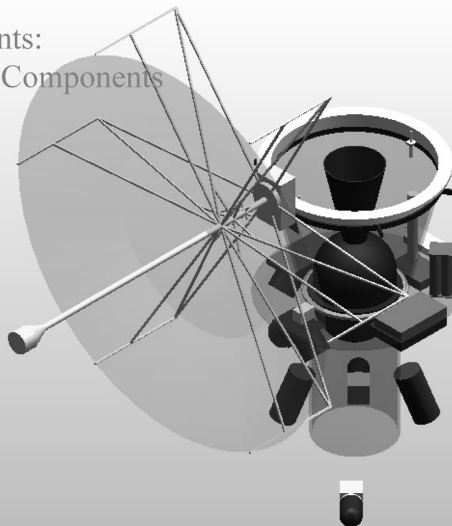
Satellite Design

At Launch



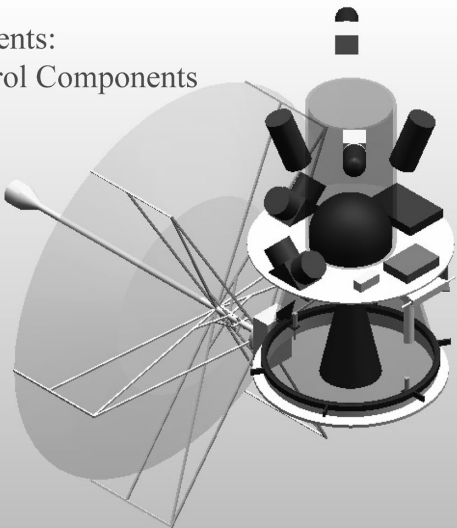
Satellite Design

Red Components:
Power Supply Components



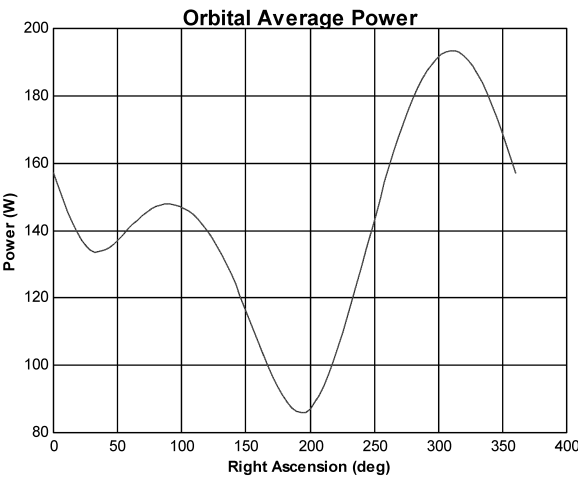
Satellite Design

Blue Components:
Attitude Control Components



Satellite Design

Average Power Generation with the Antenna Shadowing



Satellite Design

Item	Performace	Note
Satellite Mass	199.6kg 105kg 100kg	Launch Initial Dry
Power	85 W min	
Bus Volatage	28 V regulated	
Communication	X-band S-band	Mission TT&C
Outline	ϕ 1000x1700 ϕ 2420	Launch Antenna
Attitude	Zero-Momentam 3 axis Spin	Nominal Insertion
Overall Pointing Ac.	0.28 deg.	
Service Area	165km Diameter	

Introduction to MEISAT (Multi-spectral Earth Imaging Satellite) Mission

Sungdong Park

SaTReC *Initiative* Co., Ltd. (SaTReCi)

18F, Sahak Building, 929 Dunsan-dong, Seo-gu, Taejon 302-120, Republic of Korea,

(Tel) +82 42-365-7502, (Fax) +82 42-365-7549, (E-mail) sdpark@satreci.com

Abstract

The MEISAT under development by SaTReCi is a micro satellite system conveying a medium-resolution multi-spectral camera system that provides better than 10 m ground sampling distance (GSD) at a nominal altitude of 730 km. The camera system collects images in three spectral channels covering from near infrared to visible band with 50 km swath-width.

The MEISAT system is cost-effective and has a smaller size platform weighing about 100 kg compared with conventional commercial Earth observation satellites. MEISAT is eligible for various Earth imaging programs including GIS, agricultural monitoring, urban planning, environmental and disaster monitoring and resource management etc.

This paper introduces the MEISAT system focusing on the mission operation for taking the Earth images having satisfactory GSD and frequent revisit characteristic.



Introduction to MEISAT Mission (Multi-spectral Earth Imaging Satellite)

SaTReC Initiative Co., Ltd.

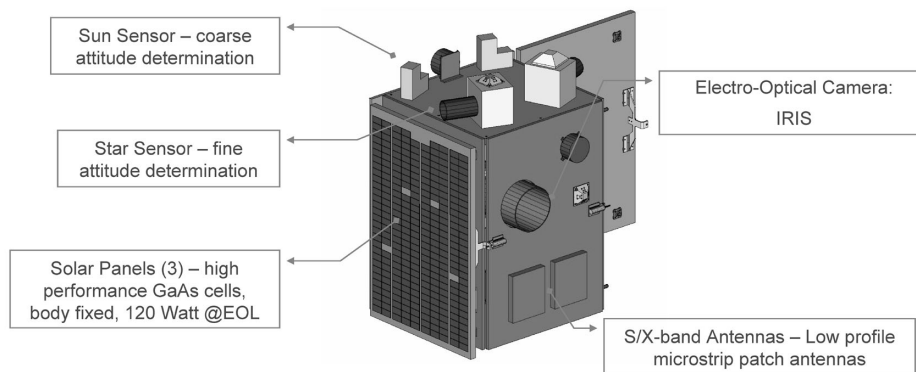
426-16 Jeonmin-dong, Yuseong-gu,
Daejeon, 305-811, Korea
(Tel) +82 42 365-7502, (Fax) +82 42 365-7549
(E-mail) sdpark@satreci.com
(Homepage) www.satreci.com

General Specifications



Items	Specification	Remarks
Mass	< 100 kg	Piggyback Launch
Input Power	120 W @ EOL	GaAs solar cell
GSD / Swathwidth	10 m / 50 km	@ 685 km Nadir
Spectral Bands	3	Visible & NIR
Mass Storage	8 Gbits	Imaging Area > 50 × 500 km ²
Attitude Control	3-Axis Stabilized	Zero-Momentum biased
Attitude Accuracy	0.5°	Full 3-axis control
Attitude Knowledge	1 arc min	

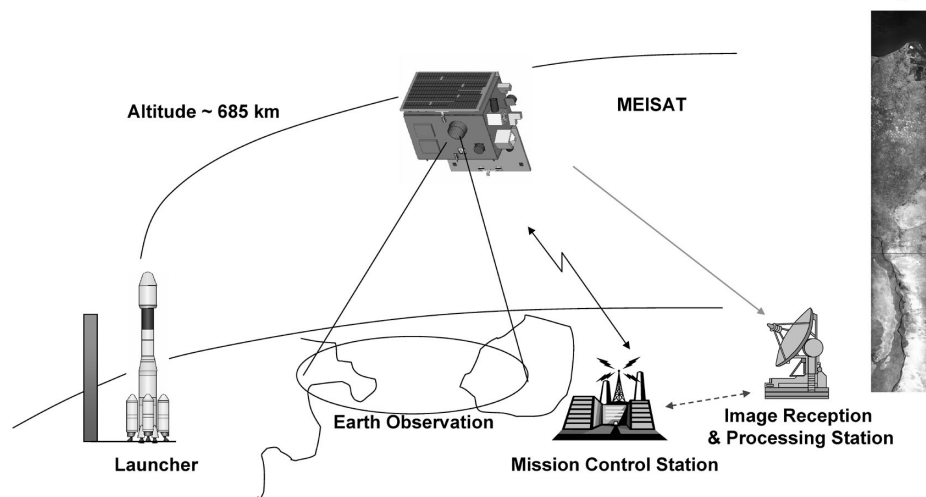
Configuration

SaTRec*i*

Introduction to MEISAT

SaTRec*i* / 3

System Context

SaTRec*i*

Introduction to MEISAT

SaTRec*i* / 4

Baseline Orbit

SaTRec*i*

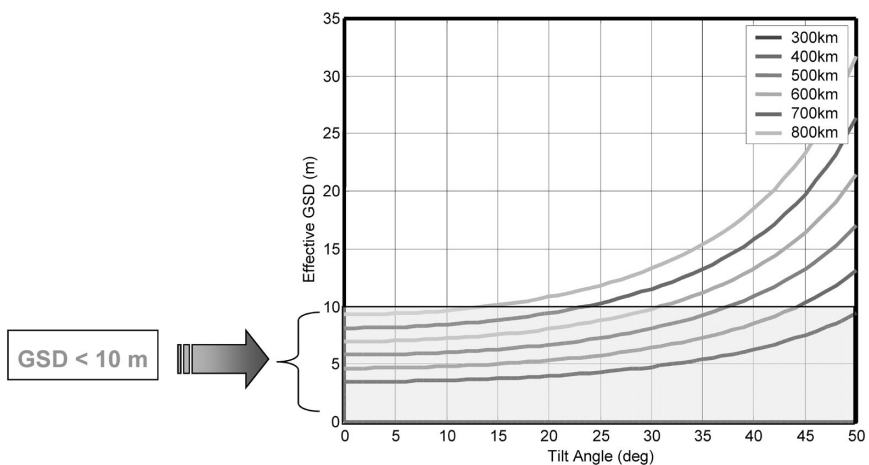
□ 685 km, Sun-synchronous

- Typical EO mission : 600 ~ 850 km sun-synchronous orbit
- Sun-synchronous orbit : constant illumination condition
- Final orbit determined by launcher selection
- Preliminary mission analysis with baseline orbit

Introduction to MEISAT

SaTRec*i* / 5

GSD vs. Altitude

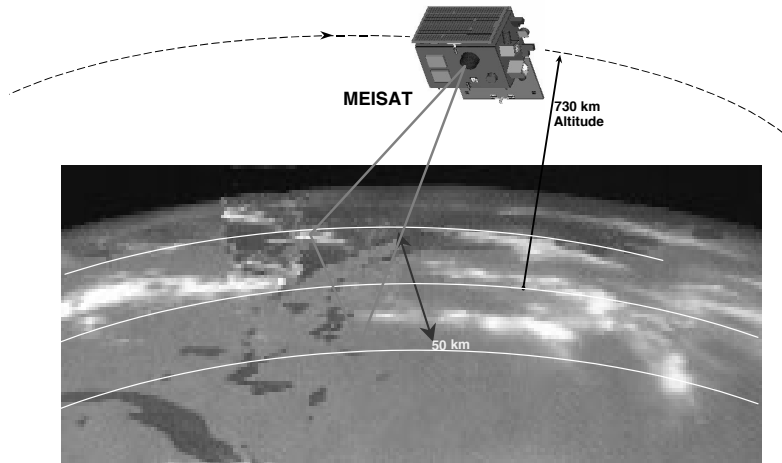
SaTRec*i*

Introduction to MEISAT

SaTRec*i* / 6

Mission Operation

SaTReCi



Introduction to MEISAT

SaTReCi / 7

Off-Nadir Imaging Capability

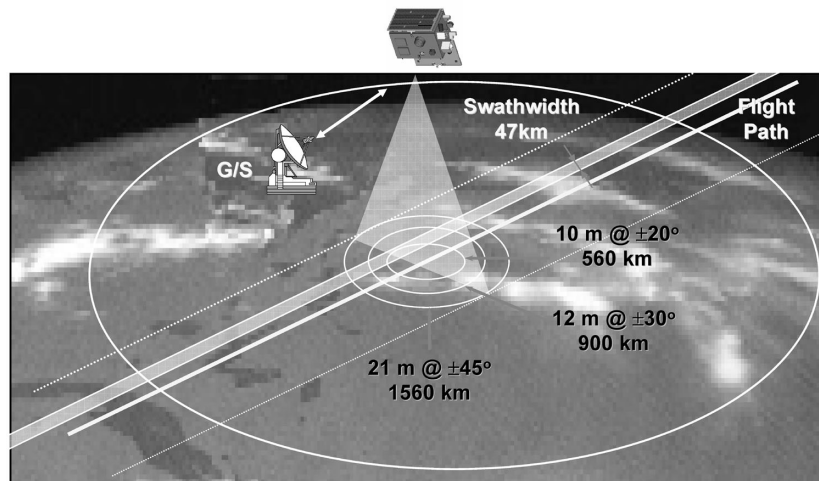
SaTReCi

- ☐ Body Tilting : $\pm 45^\circ$
- ☐ Short Revisit Period : Within 2 days
- ☐ Extended Field-of-Regard : $\pm 780\text{km}$

Introduction to MEISAT

SaTReCi / 8

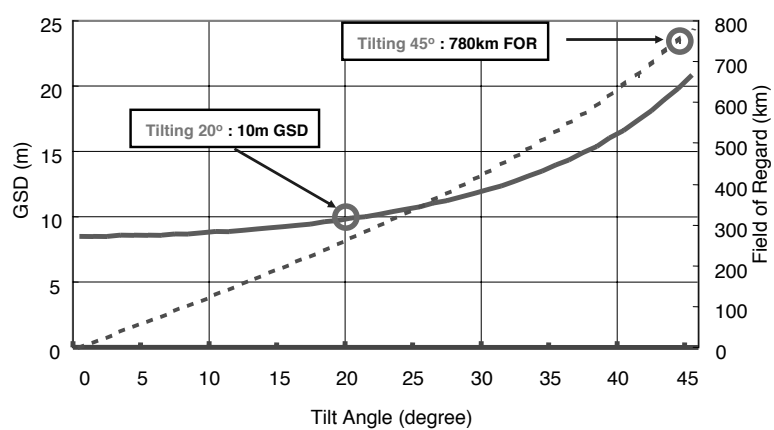
Imaging Flexibility

SaTRec*i*

Introduction to MEISAT

SaTRec*i* / 9

GSD vs. Tilting

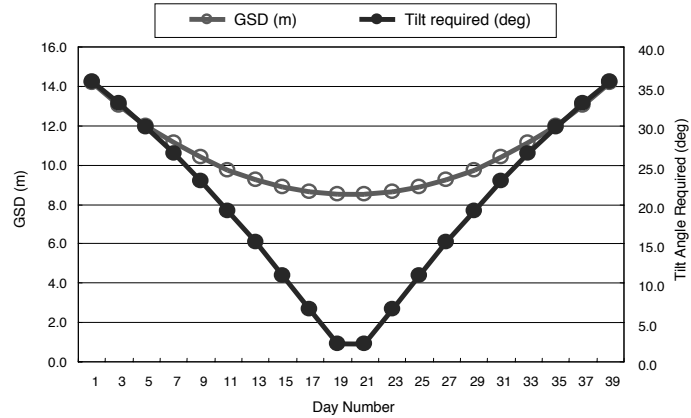
SaTRec*i*

Introduction to MEISAT

SaTRec*i* / 10

Revisit Characteristics

SaTReCi



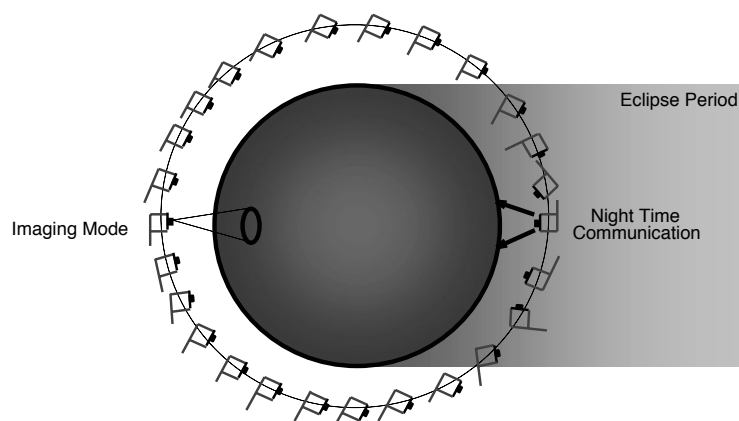
Any place can be imaged in every 2 days with GSD better than 15 m (35° of maximum tilting)

Introduction to MEISAT

SaTReCi / 11

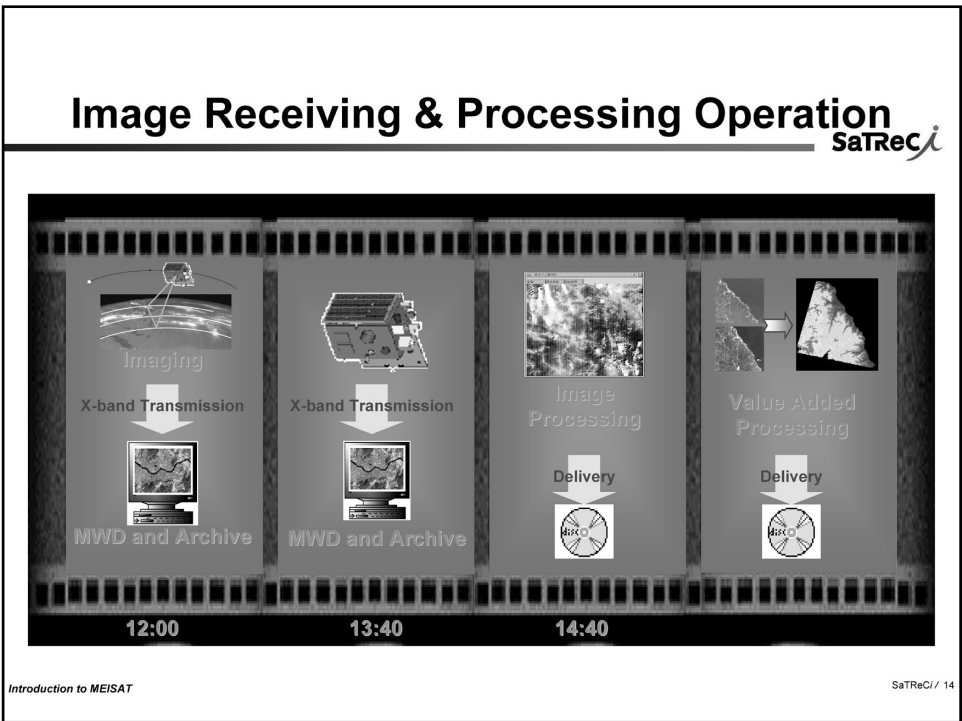
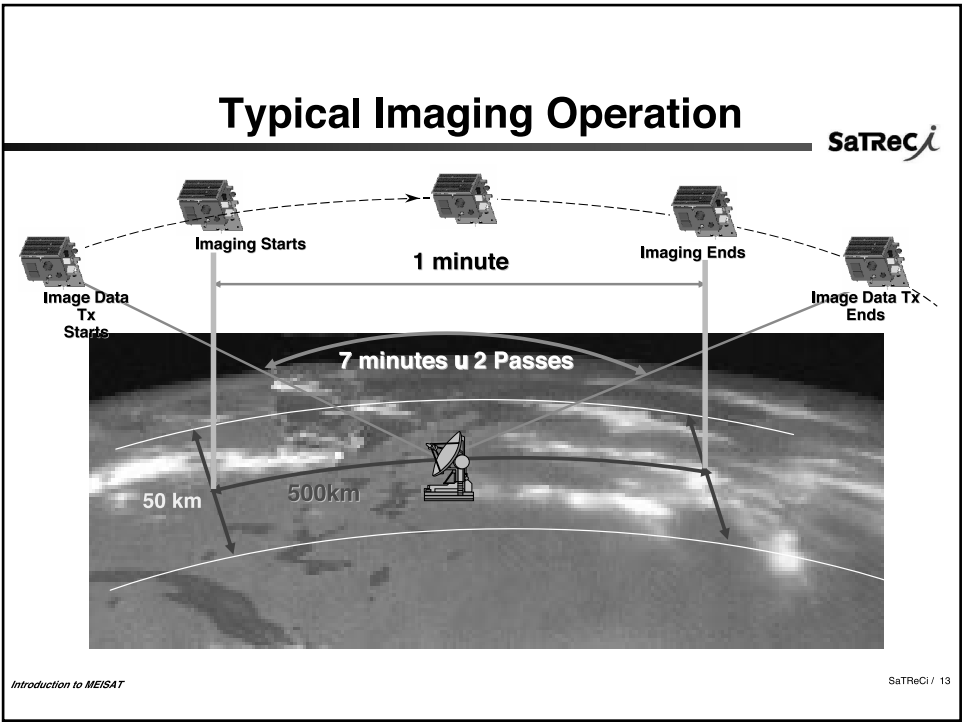
Concept of Operation

SaTReCi



Introduction to MEISAT

SaTReCi / 12



Mass Storage Capacity

SaTRec*i*

Imaging Length	240 km	320 km	400 km
Imaging Time	36 sec	48 sec	60 sec
Mass Storage	3.7 Gbits	5.0 Gbits	6.2 Gbits
Storage Margin	53.8 %	37.5 %	22.5 %
Image Data Transmission Time	6 min 14 sec	8 min 19 sec	10 min 24 sec

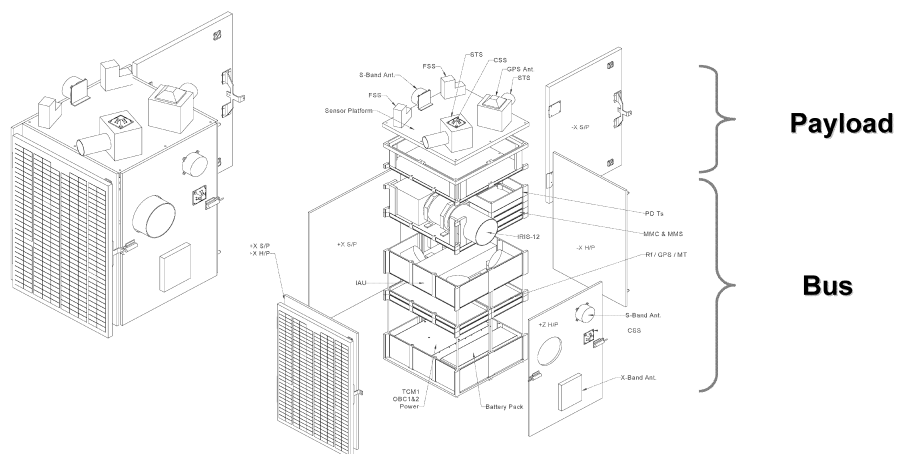
Maximum Imaging Area : $50 \times 516 \text{ km}^2$ (Using 8 Gbits)

Introduction to MEISAT

SaTRec*i* / 15

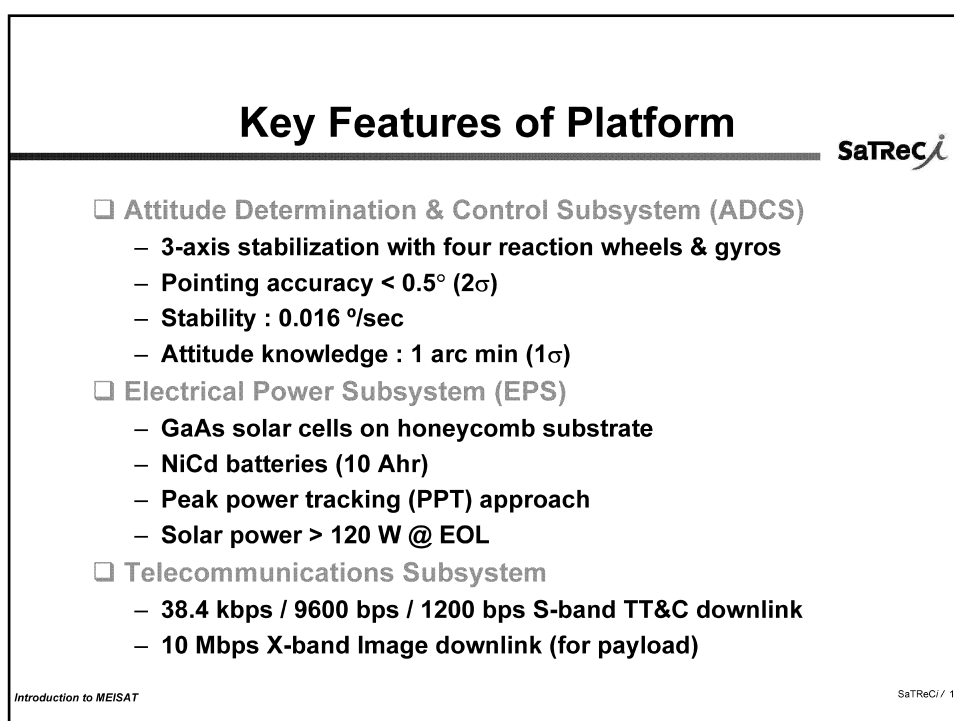
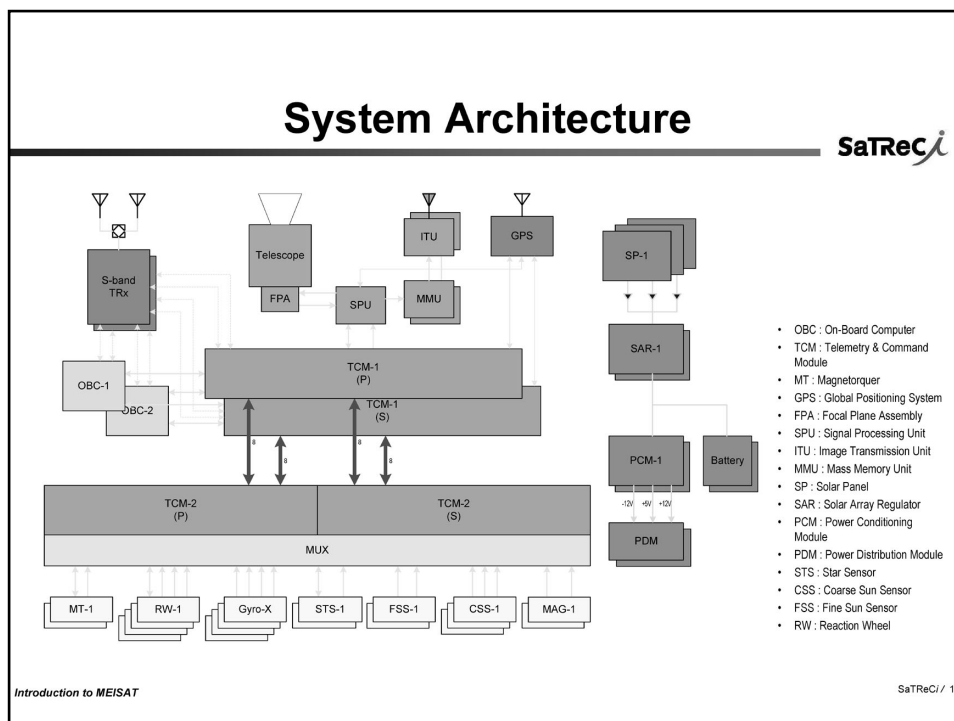
Exploded View

SaTRec*i*



Introduction to MEISAT

SaTRec*i* / 16



Key Features of Platform (cont.)

☐ Command & Data Handling Subsystem (C&DH)

- Two on-board computers (32 bits)
- Telemetry and command module
- Analog telemetry channels : up to 95
- Digital telemetry channels : up to 40
- Digital telecommand channels : 116

☐ Structure & Thermal Subsystem

- Monolithic rigid structure
- Modular structure
- Passive thermal control

Introduction to MEISAT

SaTRec / 19

Preliminary Mass & Power Budget

Item	Mass (kg)	Average Power (W)	Remarks
Platform	79	42	
C&DH	10	11	
EPS	13	3	
ACS	9	24	
RF	3	4	
Harness	3	-	
Structure	41	-	
Payload	16	13	75W @ Peak
Camera & Electronics	9	3	
ITU	2	5	
MMU	2	5	
Payload Platform	3	-	
Margin	5	-	16% DoD max
Total	100	55	120W @ Peak

Introduction to MEISAT

SaTRec / 20

Key Features of EO Payload

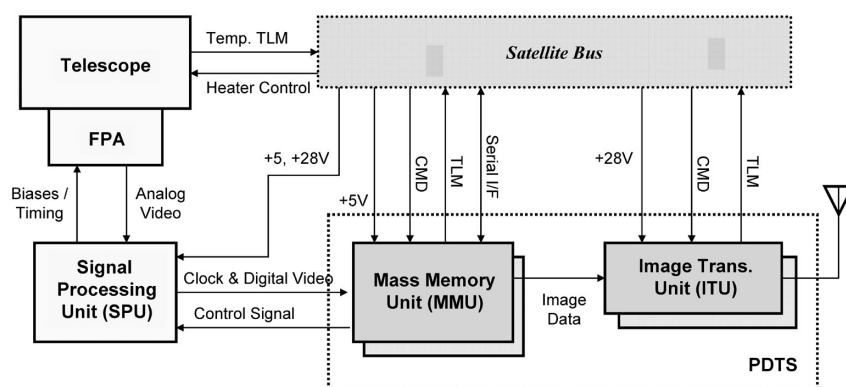


- ❑ Pushbroom imaging system
- ❑ Multi-spectral imaging in 3 bands
- ❑ 10 m GSD & 50 km Swathwidth @ 685 km
- ❑ 8 Gbits mass storage with SDRAM devices
- ❑ 10 Mbps Image Data Transmission in X-band
- ❑ Compact, Light weight, Low power Consumption

Introduction to MEISAT

SaTRec / 21

EO Payload - Block Diagram



Introduction to MEISAT

SaTRec / 22

EO Payload - Specifications



Item	Specification	Remarks
Spectral Bands	G, R, NIR	
Ground Sampling Distance (GSD)	10 m @ nadir	685 km nominal altitude
Swath-width	50 km @ nadir	685 km nominal altitude
Modulation Transfer Function (MTF)	$\geq 15\%$ @ Nyquist freq.	For entire FOV
Signal to Noise Ratio (SNR)	≥ 100	$\rho = 0.25, \theta_z = 65$ deg
Aperture Diameter	~ 120 mm	
Effective Focal Length	~ 600 mm	$F/\# = 5$
Number of Active Pixels	5,000	Swath-width > 47 km
Gain Control	Programmable	
Quantization	8 bits	
Mass Storage Capacity	8 Gbits	
Data Transmission Rate	10 Mbps	X Band, QPSK
Mass	< 12 kg	
Power Consumption	< 25 W	Peak consumption

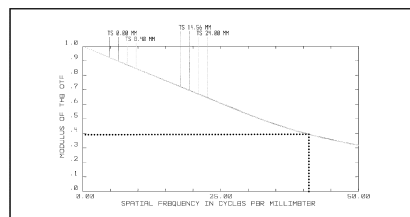
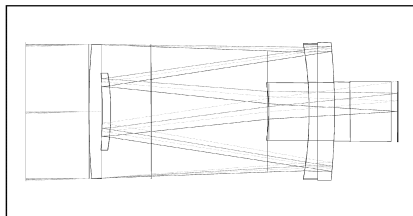
Introduction to MEISAT

SaTRecI / 23

Telescope



- ☐ On-axis Catadioptric Telescope
- ☐ Athermalization Design
- ☐ Compact & Rugged
- ☐ Baffles & Paint for Stray-Light Elimination



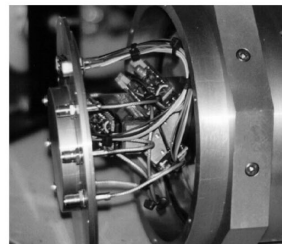
Introduction to MEISAT

SaTRecI / 24

Camera Electronics



- ☐ **Detectors : 7 - 10 μm Pixel Pitch**
 - Tri-color linear CCD or CMOS detectors
 - Three linear CCD or CMOS detectors + Prism block
- ☐ **Active Pixels : 5,000 for All Bands**
- ☐ **Programmable Gain and Offset Compensation**
- ☐ **10-bit Quantization (8-bit Transmission)**



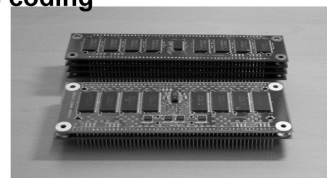
Introduction to MEISAT

SaTRecI / 25

Mass Memory Unit



- ☐ **8 Gbits Mass Storage with SDRAM Devices**
- ☐ **High-speed Real-time Data Storage**
- ☐ **Real-time Transmission of Quick-look Images**
- ☐ **SDRAM Modules : low power, small & fast**
- ☐ **Centralized & Distributed Control Architecture**
- ☐ **Module Design : easy expansion of higher capacity**
- ☐ **Fault Tolerant : redundancy, EDAC & RS coding**



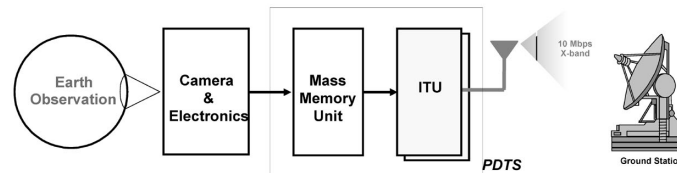
Introduction to MEISAT

SaTRecI / 26

Image Transmission Unit



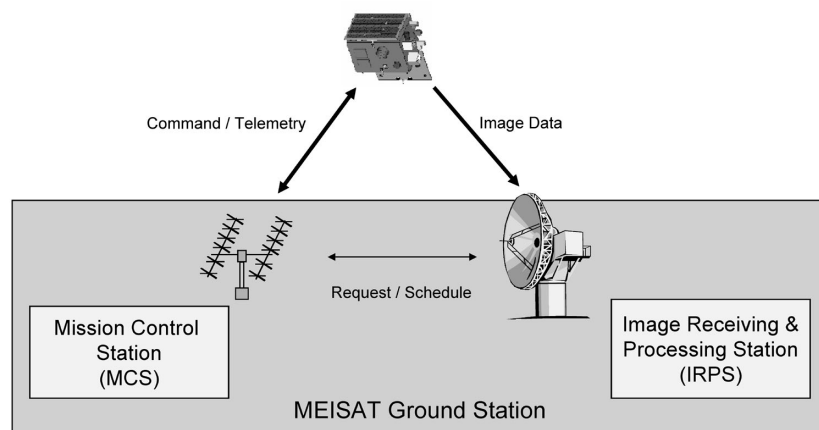
- ☐ High-speed Transmission : 10 Mbps
- ☐ QPSK Modulation
- ☐ X-Band : dedicated frequency band for EO mission
- ☐ Microstrip Patch Antenna for Compactness
- ☐ Full Redundancy



Introduction to MEISAT

SaTRec / 27

MEISAT Ground Station



Introduction to MEISAT

SaTRec / 28

Mission Control Station (MCS)

SaTRec*i*

- ❑ **Satellite Tracking**
 - Multi-satellite control
 - Autonomous satellite tracking
 - Autonomous Doppler frequency offset control
- ❑ **Satellite Control and Health Check**
 - Telemetry and commanding
 - OBC communication
 - File upload/download
 - Attitude control
- ❑ **Payload Operations**
 - Imaging operations : Scheduling, Targeting, and Attitude maneuvering
 - Operation status check



Introduction to MEISAT

SaTRec*i* / 29

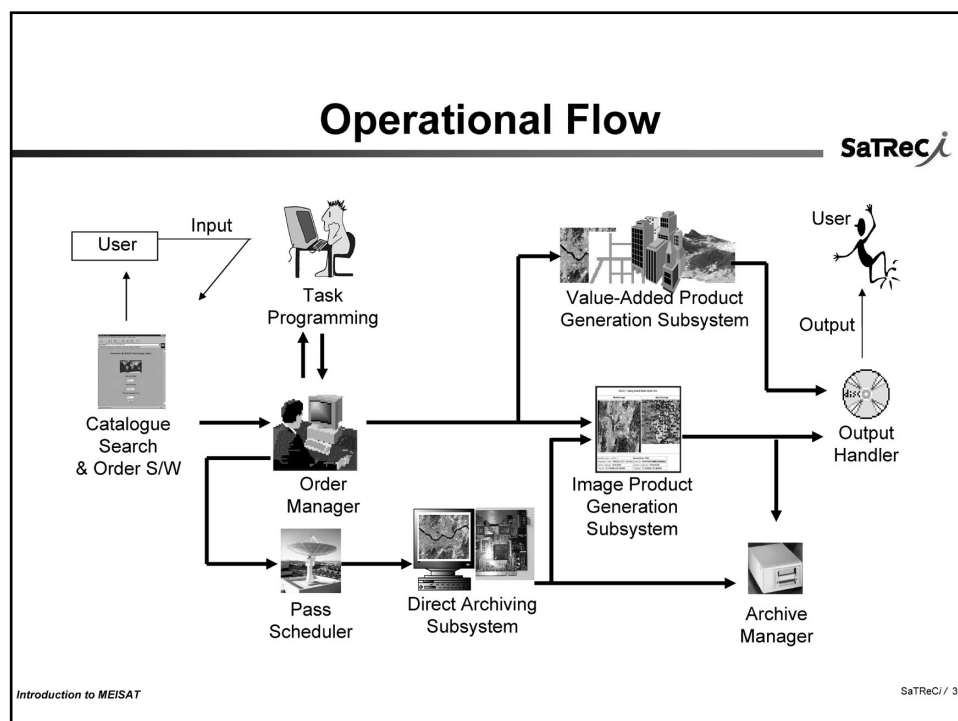
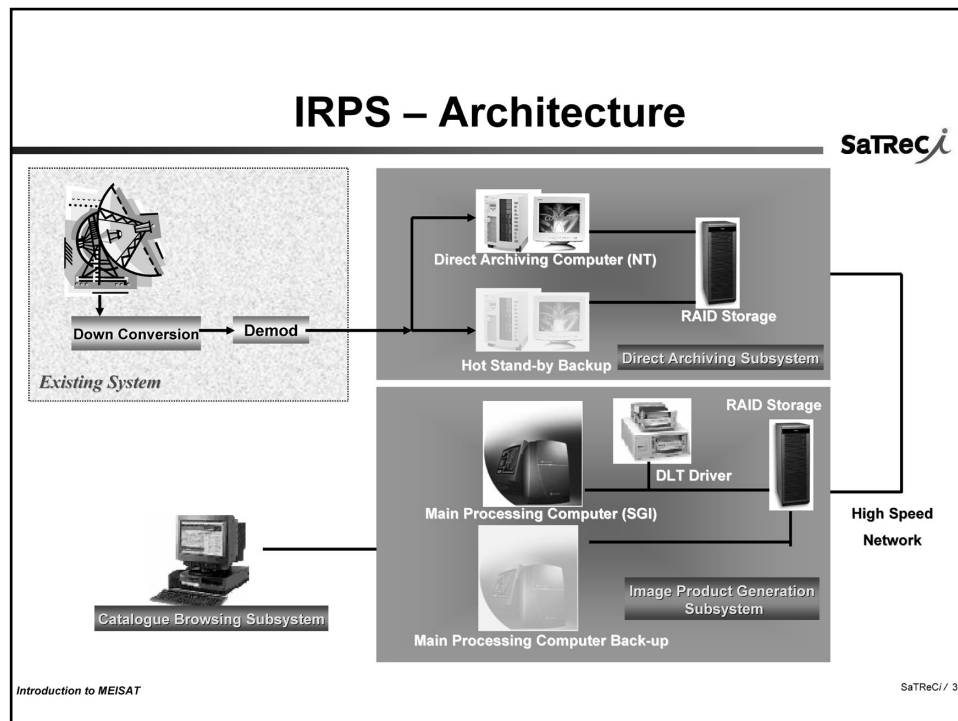
Image Receiving & Processing Station (IRPS)

SaTRec*i*

- ❑ **Direct Archiving**
 - Maximum 190 Mbps ingest speed
 - Real time moving window display
 - Software formatting
 - Image storage capacity : 100 GBytes
- ❑ **Image Product Generation**
 - Automatic or semi-automatic cloud assessment
 - Catalogue & browse images
 - Radiometrically corrected
 - Systematically geocoded
 - Precision geocoded
 - Ortho-rectified
 - DEM
- ❑ **Catalogue Browsing**
 - Web-based catalogue and browse image search

Introduction to MEISAT

SaTRec*i* / 30



Value-Added Product Generation Subsystem

SaTRec*i*

Value-Added Products

Precision Correction

Ortho Correction

DEM

☐ Common and essential data sets for user applications

☐ Key Issues

- Accuracy
- User-friendly interface
- Reasonable number of GCPs

Introduction to MEISAT

SaTRec*i* / 33

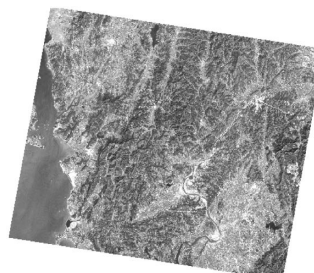
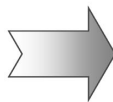
Precision Correction

SaTRec*i*

- ☐ Geometric accuracy can be improved by precision correction using ground control points (GCPs)
- ☐ Requires about 5 GCPs
- ☐ Error < 1.5 pixel



Raw Satellite Image



Precision Corrected Image

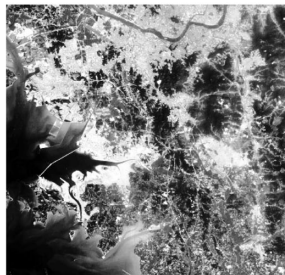
Introduction to MEISAT

SaTRec*i* / 34

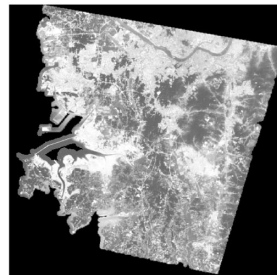
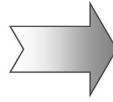
Ortho Correction

SaTRec*i*

- ☐ Geometric accuracy can be improved more by ortho-rectification using DEM
- ☐ Requires about 5 GCPs
- ☐ Error < 1.0 pixel



Raw Satellite Image



Ortho-Corrected Image

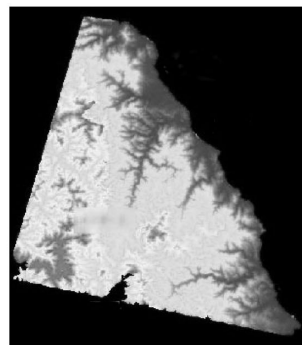
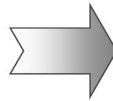
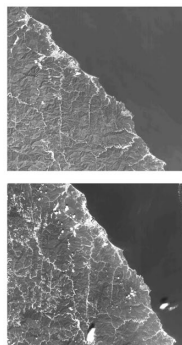
Introduction to MEISAT

SaTRec*i* / 35

DEM Generation

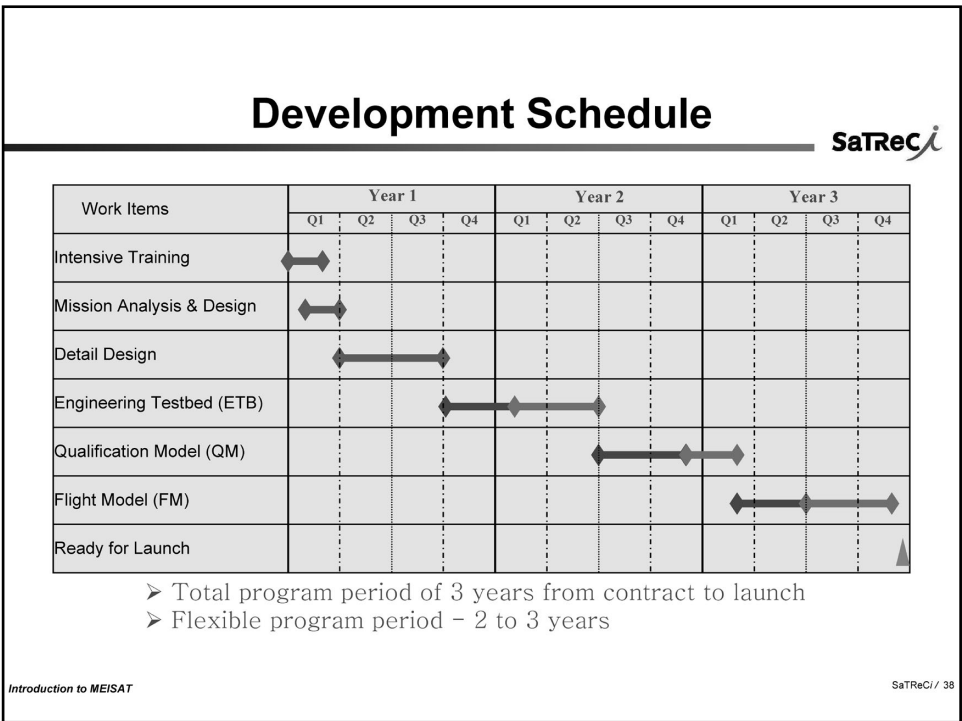
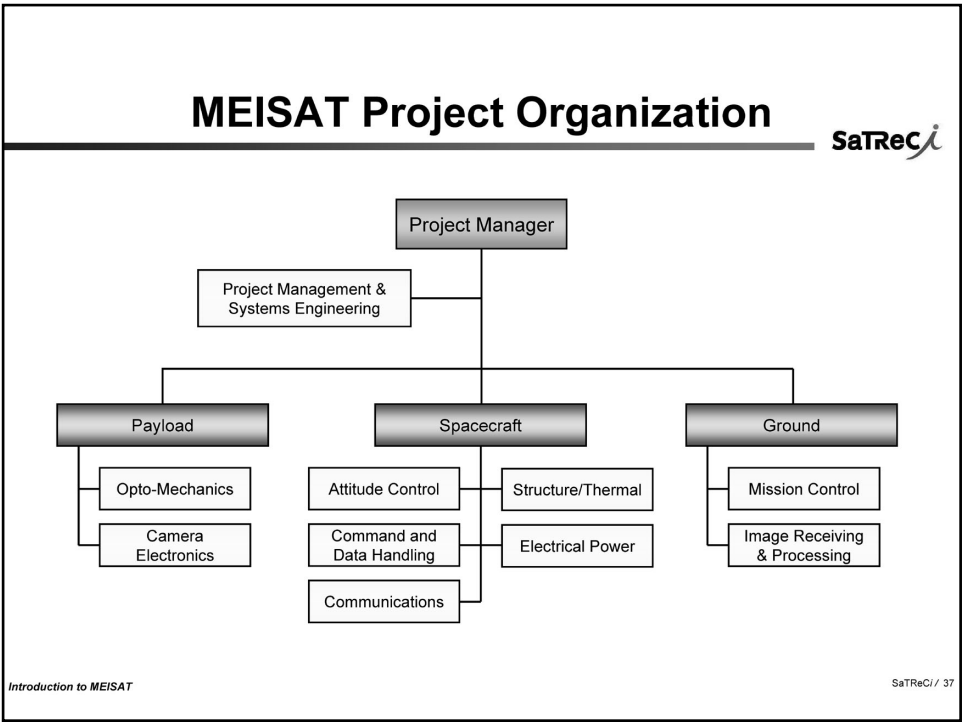
SaTRec*i*

- ☐ Requires 10 to 12 GCPs
- ☐ Takes 30 Minutes
- ☐ Error : Vertical – 7 m, Horizontal – 11 m



Introduction to MEISAT

SaTRec*i* / 36



Model Philosophy

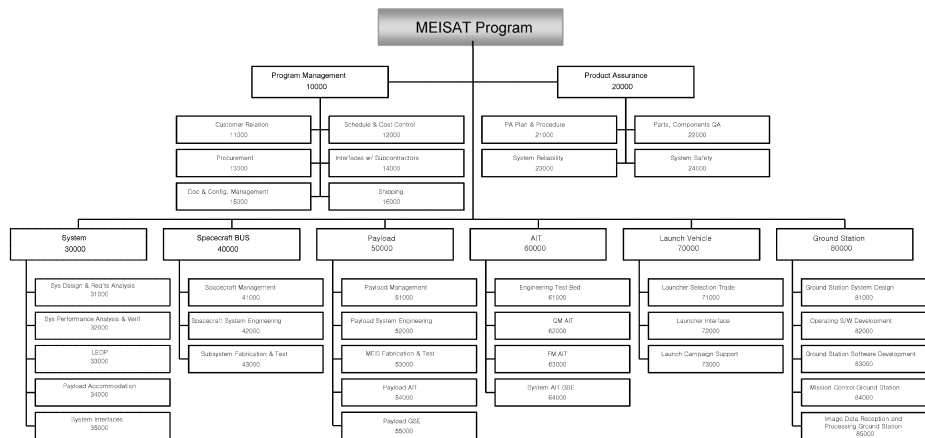


	Engineering Testbed (ETB)	Qualification Model (QM)	Flight Model (FM)
Purpose	<ul style="list-style-type: none"> • Functional verification • Software testbed 	<ul style="list-style-type: none"> • Qualification test • Full functional verification • Spare modules for FM 	<ul style="list-style-type: none"> • Flight
Part/Component Grade	<ul style="list-style-type: none"> • Use commercial or industrial grade 	<ul style="list-style-type: none"> • Use as much MIL grade or flight-heritage components as possible • Industrial grade components may be used in some exceptional occasions 	<ul style="list-style-type: none"> • Use as much MIL grade or flight-heritage components as possible • Industrial grade components may be used in some exceptional occasions
Configuration	<ul style="list-style-type: none"> • Modules must have the same function and interface to FM 	<ul style="list-style-type: none"> • Except some expensive components, all the modules must be identical as flight configuration including payloads 	<ul style="list-style-type: none"> • All the modules must be integrated as flight configuration
Test	<ul style="list-style-type: none"> • Functional checkout • Interface checkout 	<ul style="list-style-type: none"> • Qualification level • Aging test 	<ul style="list-style-type: none"> • Acceptance level • Reduced level

Introduction to MEISAT

SaTRec / 39

Work Breakdown Structure (WBS)



Introduction to MEISAT

SaTRec / 40

Figures of Merit for Image Quality



- ☐ **How small object can you recognize ?**
 - Ground Sampling Distance (GSD)
 - Optical quality (MTF)
- ☐ **How sharp image can you get ?**
 - Optical quality (MTF, SNR)
 - Platform stability
- ☐ **How accurately objects can be located ?**
 - Ephemeris (satellite position) & time
 - Satellite attitude
 - Image processing algorithm
- ☐ **How often a certain target can be observed ?**
 - Orbital characteristics
 - Off-nadir imaging capability

Introduction to MEISAT

SaTRec / 41

Key Features of Proposed System



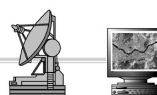
Precision Camera

- ☐ High Resolution & Wide Swath
 - GSD : 10 m @685km
 - Swathwidth : 50 km
- ☐ Multi-spectral Imaging Capability
 - # of Spectral Bands : 3
- ☐ Variable Gain
- ☐ Precision Optics & Low Noise Camera Electronics
- ☐ 8 Gbits of Image Data Storage
- ☐ 10 Mbps Downlink in X-band



Stable & Agile Platform

- ☐ 3-Axis Stabilization based on Four Reaction Wheels & Gyros
- ☐ +/- 45 ° of Off-Nadir Viewing
- ☐ Accurate Attitude Control
 - < 0.5° of Pointing
 - 0.016 °/sec of Stability
 - 1 arc min of Knowledge
- ☐ Rigid Structure
 - Monolithic
 - Body fixed Solar Arrays



Ground Processing

- ☐ Direct Receiving & Archiving
 - Capability : up to 190 Mbps
 - Moving Window Display
 - Software Formatting
- ☐ Image Product Generation
 - Radiometrically Corrected
 - Systematically Geocoded
 - Precision Geocoded
 - Value Added Products
- ☐ Catalogue & Browsing

Introduction to MEISAT

SaTRec / 42

Summary



- ❑ **MEISAT is a technologically competent Earth observation satellite system.**
 - **World's best microsatellite system for Earth observation mission**
 - **Application-driven satellite and ground systems**
 - **High growth potential**
- ❑ **Self-standing capability can be built-up for future missions.**
 - **The most effective and efficient approach in terms of development cost & technology transfer**
 - **Continuous engineering support for facility set up, shadow satellite development & engineering capability enhancement**
 - **Long-term partnership in joint marketing of space systems and image products**

**SPECIAL PUBLICATION OF NATIONAL
AEROSPACE LABORATORY
SP-58T**

航空宇宙技術研究所特別資料SP-58T号(欧文)

平成15年6月発行

発行所 独立行政法人航空宇宙技術研究所
東京都調布市深大寺東町7-44-1
電話(0422)40-3935 ㊦182-8522
印刷所 株式会社 東京プレス
東京都板橋区桜川2-27-12

Published by
NATIONAL AEROSPACE LABORATORY OF JAPAN
7-44-1 Jindaijihigashi-Machi, Chofu, Tokyo
JAPAN

©2003 独立行政法人 航空宇宙技術研究所

※本書(誌)の一部または全部を著作権法の定める範囲を超え、無断で
複写、複製、転載、テープ化およびファイル化することを禁じます。
※本書(誌)からの複写、転載等を希望される場合は、情報技術課資料
係にご連絡下さい。
※本書(誌)中、本文については再生紙を使用しております。

