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JAXAのロケット・衛星の非デブリ化研究について

Debris mitigation research of rocket and satellite, as JAXA's research

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今後のデブリ推移によると、宇宙開発を継続的に維持発展するにはこれ以上のデブリ発生は許されない状況にあり、運用終了後のロケットや衛星に対する有用軌道からの移動（非デブリ化）は必須の運用となりつつある。さらには、非デブリ化の手段として地上への再突入を行う場合は、地上リスクが高まることがある。
一方、非デブリ化の機能を付加するには追加費用と性能ロスが発生するため、市場競争力の妨げになる可能性がある。
そこで、JAXA は今後に打上げが予定されているロケットや衛星に向けて、競争力を可能な限り維持した非デブリ化方策について総合的な研究開発を開始した。本講演では、全体計画とその進捗について報告する。
具体的には、①非デブリ化機能の追加について、②競争力の維持方策について、③地上リスク評価の適正化についての 3 点である。

Debris mitigation of rockets and satellites is essential operation for the future space activity.

In addition, when the spacecraft accomplish the controlled atmospheric reentry, the ground risk for public may be increase.

On the other hand, the debris mitigation function effect the additional cost and the loss of capability, which leads the loss of commercial competitiveness.

Therefore, JAXA started the integral research for debris mitigation method with maintaining the competitiveness.

1. Add the debris mitigation function, 2. Maintaining the competitiveness, 3. Appropriate ground safety risk assesment, are major topics.

Debris mitigation research of rocket and satellite, as JAXA's research

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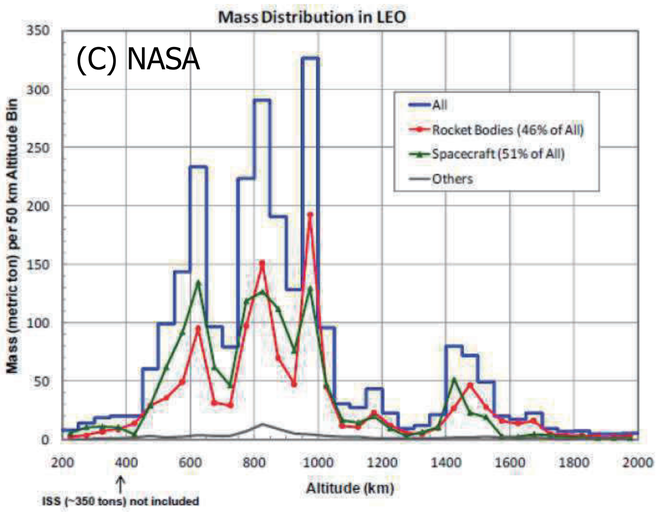
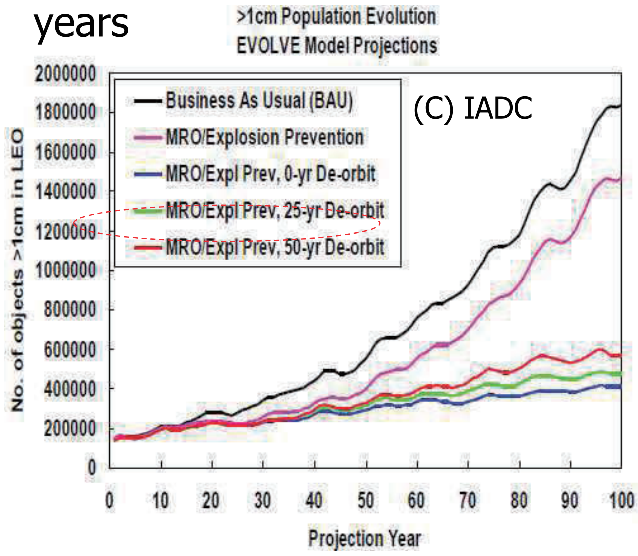
Outline

1. Debris problem and main requirements
2. World trend to mitigate rocket debris
3. H-IIA/B and Epsilon status
4. JAXA's satellites status
5. Japan's research activity for next rocket and spacecraft
6. Summary

1. Debris problem and main requirements

- A lot of debris are exist
  - Under 2,000km altitude
  - GSO altitude (36,000km)
- 46% is Rocket bodies
- 10times debris in 100years, if continue this space operation
- Almost no increase, if prevent the separation and De-orbit in 25 years





1. Debris problem and main requirements

- 2002 : IADC Space Debris Mitigation Guidelines

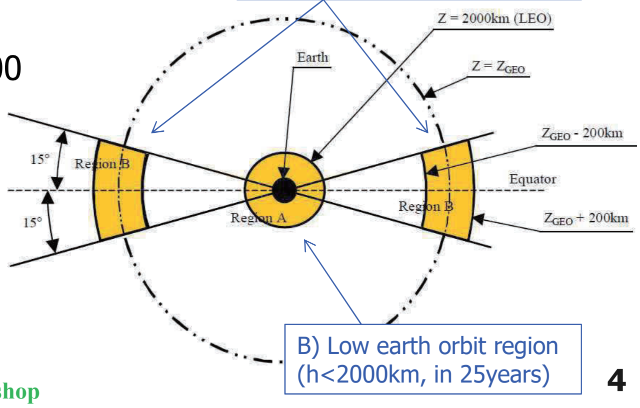
(JAXA) 2004: JMR-003、003A
Space Debris Mitigation Standard

- 2007 : UNCOPUOS Space Debris Mitigation Guidelines
- 2010 : ISO Space debris mitigation requirements
  - De-orbit from protected orbit
    - A) Geostationary orbit region (h±200km, Latitude±15deg)
    - B) Low earth orbit region (h<2000km, in 25years)
  - Ground safety (Best effort)
    - Fragmentation Risk (Ec) < 1/10,000

(JAXA) 2011: JMR-003B
2014: JMR-003C

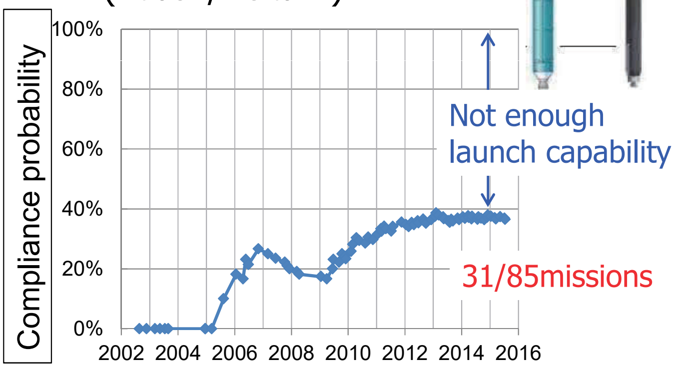
Space Debris Mitigation Standard (JMR-003) applies to all space systems developed by JAXA.
As a rule, all satellites developed by JAXA comply the above requirements.

A) Geostationary orbit region (h±200km, Latitude±15eeg)



2. World trend to mitigate rocket debris [U.S]

- Requirement
  - U.S. Government Orbital Debris Mitigation Standard Practices, compliant ISO
    ①De-orbit in 25 years and Ec<10^-4 or
    ②Transfer to Disposal orbit, or ③Direct Recovery
- Current operation
  - EELV (AtlasV/DeltaIV)



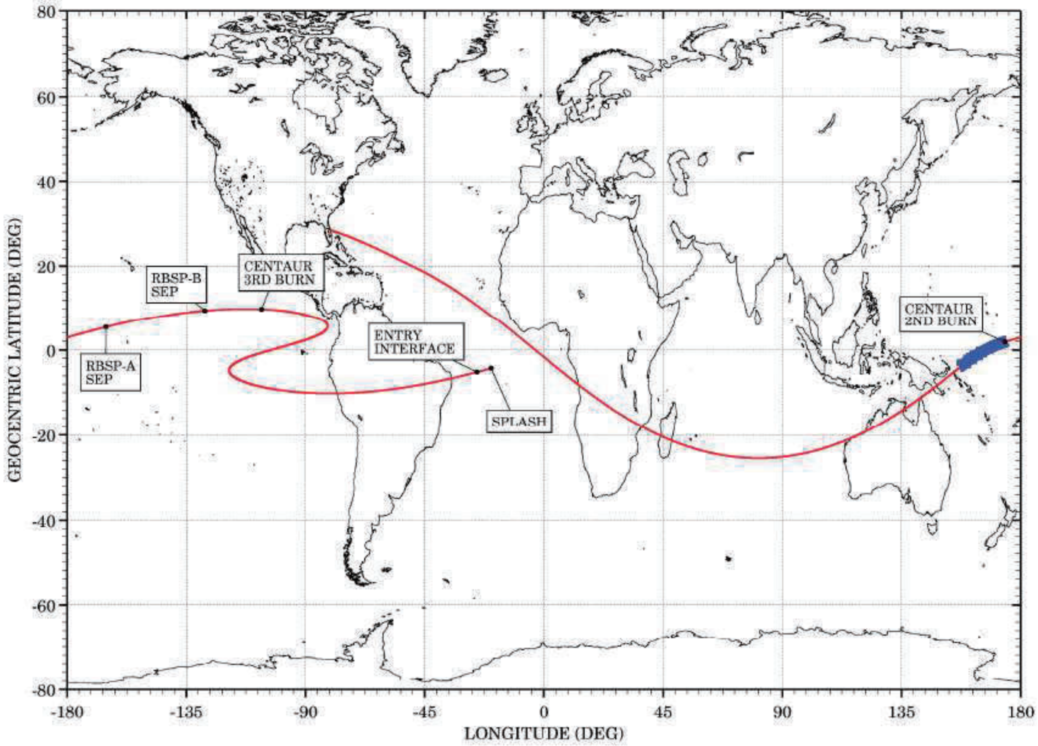
  - Falcon9 18missions@2015
    [Compliance]
    - 3 controlled re-entry ①
    - 1 Disposal orbit ②

    [Not compliance]
    - 9 natural re-entry completed
    - 5 in protected orbit

- Future
  - Toward almost 100% compliance. (till 2020 at Sep/2012 AIAA paper)

Ref : Atlas V GTO mission controlled re-entry

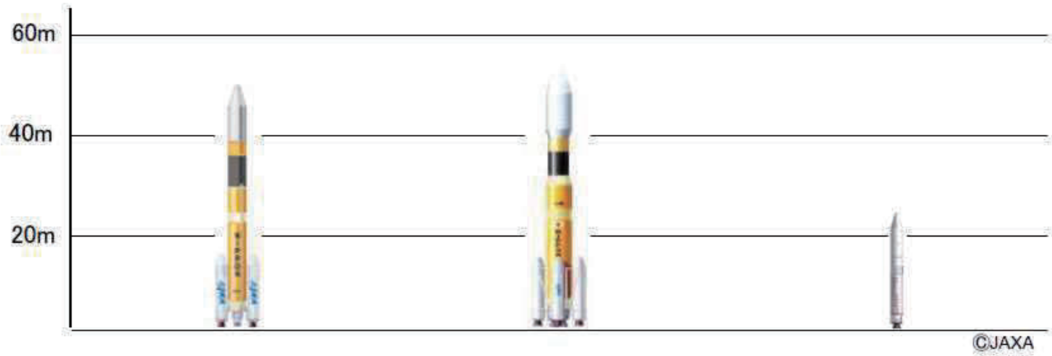
(C) NASA (UN/COPOUS/STSC2013 presentation)



2. World trend to mitigate rocket debris [Europe]

- **Requirement**
  - The French Space Operation Act, compliant ISO
    ① Controlled re-entry (CRT) from low earth protected region
    If impossible, De-orbit in 25 years and not interfere in one hundred years
    ② GSO protected region: De-orbit in one year and not interfere in one hundred years
    ③ Re-entry risk : Ec<2 x 10^-5 at controlled re-entry.
    If impossible, to do the best effort for satisfying Ec<10^-4 with natural decay
- **Current operation**
  - Ariane5 : 5 CRT / 84 success. Basically No action except ATV mission
  - Vega : 3 CRT and 3 De-orbit in 25years life time / 6 orbital flight
- **Future**
  - Ariane6 (2020 debut) plan to do controlled re-entry almost all mission, with upper stage new engine Vinci, which prepare re-ignition function.

3. H-IIA/B and Epsilon status



Name	H-IIA	H-IIB	Epsilon
Length	53m	57m	24m
Propellant	Liquid (LOX/LH2)	Liquid (LOX/LH2)	Solid
Success/Launch	28/29	5/5	1/1
Success rate	97%	100%	100%
Launch ability	GTO(*): 4.0ton (202) 5.8ton (204) SSO(*): 3.9ton (202)	GTO(*): 8ton HTV orbit: 16.5ton	LEO: 1,200kg SSO: 450kg (500km)

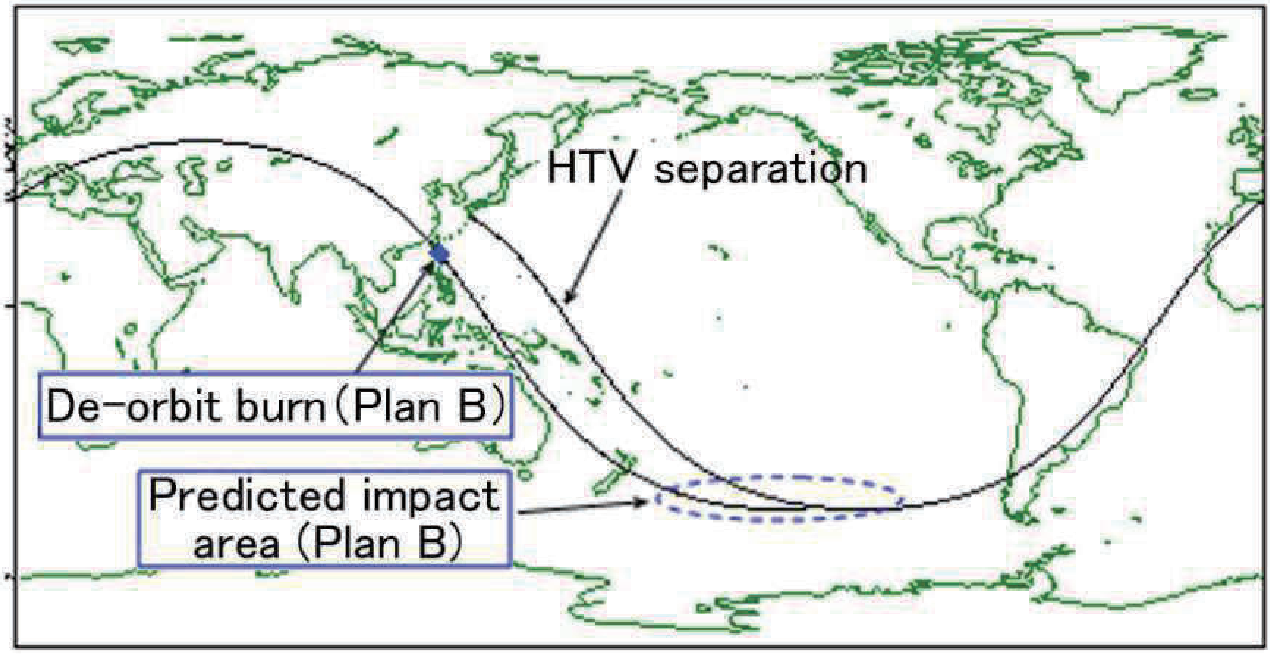
(*) GTO: Δ V=1,800m/s, SSO: 800km

3. H-IIA/B and Epsilon status

- H-IIB/HTV take controlled re-entry, but other H-IIA/B and Epsilon don't do any de-orbit for debris mitigation.
- Under developing de-orbit function, which compliant to 25 years rule, for near future

Rocket	Mission	Life time (in 25yeas?)	Ground risk (Ec)	Note
H-IIA	GTO (ΔV=1840m/s)	250x36000km, 28.5deg × 100years~	× Big casualty area	In 25 years will be realized in a few years, if extra launch capability
	SSO	500~800km △ Depend on altitude	× Big casualty area	
	GTO (ΔV=1500m/s)	2700x36000km, 20deg ○ Not inside protected region		Long coast technique and 60% throttling thrust
H-IIB	HTV	200x300km,51.65deg ○	○	Controlled re-entry
Epsilon	Extended Elliptical orbit	200 x 30700km, 31deg ○	○	
	SSO (h<600km)	○	○	
	LEO･SSO (h>600km)	×	○	Two debris (3rd stage and PBS)

Ref : H-IIB HTV mission controlled re-entry



4. JAXA' satellites status

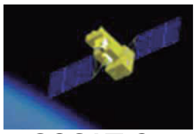
- JAXA開発衛星
  スペースデブリ発生防止標準を適用しており、原則として世界共通ルールを遵守。
  Space Debris Mitigation Standard (JMR-003) applies to all space systems developed by JAXA. As a rule, all satellites developed by JAXA comply the requirements.

- 地球観測衛星のデオービット De-orbit of Earth observation satellites
  運用終了時に近地点高度を下げ、25年以内に自然落下する軌道に退避する計画。デオービットに必要な推進薬を搭載する。（下記衛星ではGCOM-Cが最多。）


GCOM-W（H 700×700km）


GCOM-C（H 800×800km）

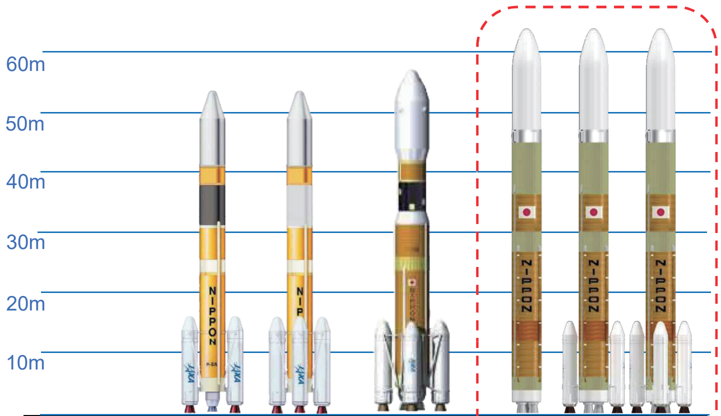

ALOS-2（H 628×628km）


GOSAT-2（H 613×613km）

⇒ Lower the perigee altitude (orbital lifetime < 25 years)

- 地球観測衛星の落下危険度
  再突入時に溶融しない残存物による傷害予測数（Ec）は1×10^{-4}未満を満足。
  残存物で大きな割合を占めているのは高融点のチタン合金製の推進薬タンク。
  ⇒ 衛星の溶融率を向上させるためにはタンクの溶融化が効果的。
  JAXAではアルミ合金ライナの複合材推薬タンクを2013年より開発中。

5. Japan's research activity for next rocket and spacecraft



	H−ⅡA	H−ⅡB	H3
Launch Capability (GTO)	3ton～4.8ton ΔV1500m/s	16.5ton (HTV orbit)	～6.5ton ΔV1500m/s
Operation	2001～	2009～	2020～
Launch Results	28/29	5/5	−

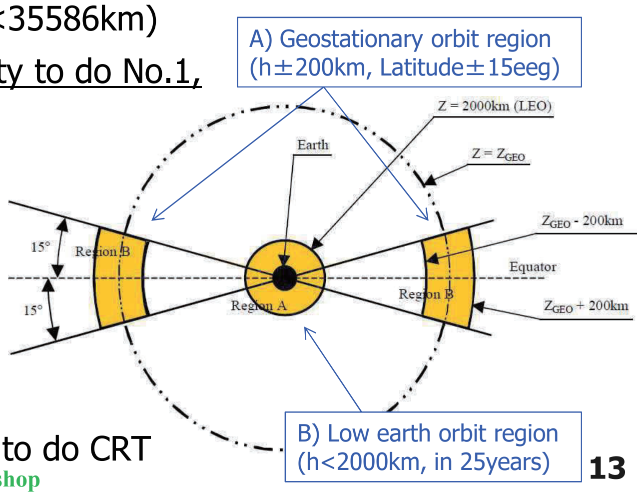
Cost performance

High reliability

Flexible service

5. Japan's research activity for next rocket and spacecraft

- H3 Debris mitigation policy (Tentative, under discussion)
  1. Avoid the interfere to protected region, with one of the following method
     - ① Controlled re-entry
     - ② De-orbit to not protected region
       - A) Earth escape trajectory
       - B) Outside of GEO protected region (h>35,986km)
       - C) LEO~GEO orbit (2000km<h<35586km)
  2. If there is not enough launch capability to do No.1, Natural re-entry in 25 years
  - Equivalent debris mitigation operation, to Europe and U.S. future competitor
- Epsilon Debris mitigation research
  - Minimizing the debris
  - Cost and capability Impact evaluation to do CRT



5. Japan's research activity for next rocket and spacecraft

- Trade-off status for H3 debris mitigation

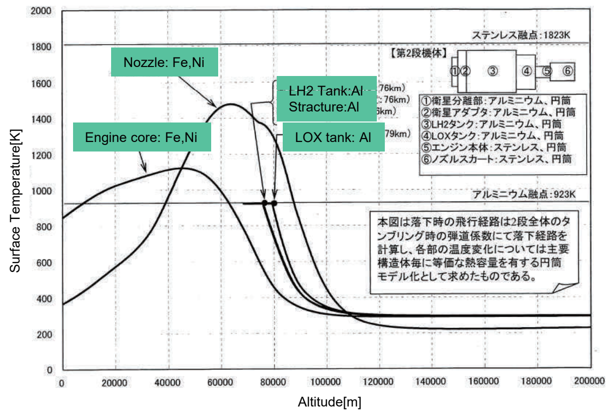
Mission	(1) Baseline	(2) If impossible to do (1)	H-IIA/B
SSO (h=500km)	Controlled re-entry	No de-orbit. (Natural re-entry in 25 years)	No de-orbit
SSO (600km<h)		Decrease the perigee altitude and natural re-entry in 25 years	
GTO (ΔV=1500m/s)	No interference to protected region. (between LEO and GEO)		Same
GTO (ΔV=1840m/s)	A. De-orbit to between LEO and GEO B. Controlled re-entry	Decrease the perigee altitude and natural re-entry in 25 years	No de-orbit
HTV-X	Controlled re-entry		Same

5. Japan's research activity for next rocket and spacecraft

- Design for demise
  - Change material from Ti to CFRP, from Fe to Al
  - Will check the effect to ground risk, launch capability and cost.

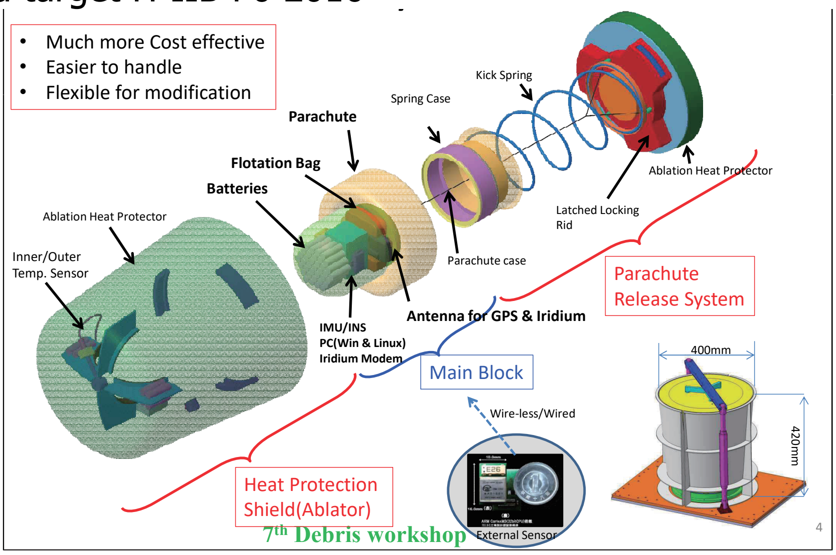
H-IIA Random reentry Orsat-J results

01 Ambient Temp. He Pressure Vessel
02 Cryogenic Temp. He Pressure Vessel
09 Heat exchanger inside LOX tank
15 Gas thruster
16 Feedline Pipes
19 Pneumatic Solenoid (4way)
20 Pneumatic Solenoid (3way)
23 Engine Core
24 Nozzle



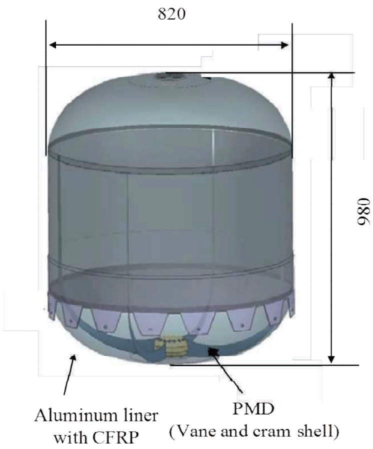
5. Japan's research activity for next rocket and spacecraft

- Re-entry data acquisition system and CFD simulation
  - Purpose : Validate the analyses necessary to assess the re-entry risk.
  - Measure the temperatures of upper stage components and pressure, and data transmit after drop to sea
  - On board target H-IIB F6 2016



5. Japan's research activity for next rocket and spacecraft

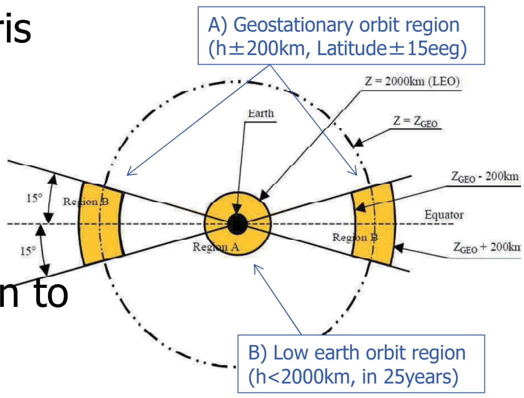
- Composite overwrapped propellant tank (Design for demise)
  - Purpose : Improve the demisability of LEO satellites. Replace the titanium tank of LEO satellite that is one of the most hazardous component at the time of natural re-entry.
  - The basic demise evaluation was conducted by ORSAT-J and arc wind tunnel tests with specimen. JAXA will conduct more detail analysis.



Parameters	Requirements
MEOP	2.76MPa
Proof Pressure	3.45MPa
Burst Pressure	4.14MPa
Temperature Range	5～60°C
Total Volume	0.43m³
Propellant	Hydrazine (N_2H_4)
Other Fluid	He, H_2O, IPA, N_2
Mass	≤23.3kg
On Orbit Life	≥15years

6. Summary

- What is main requirement for rocket debris mitigation ?
  - A) De-orbit from protected orbit
  - B) Ground safety



- "A" will be world standard and the mission to compliant to "B" will be increased, from Europe and U.S. trend.

- Japan's vehicle H-IIA/B and Epsilon take some debris mitigation and H3 will avoid the interfere to protected region, which will be world standard.

- Design for demise and Re-entry data acquisition system are also researched, to do more debris mitigation.