R&D Plans for Japanese Next Generation Satellite Communications Systems

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Broadband Satellite Network Group
Communications Research Laboratory

Independent Administrative Institution
(owned by Japanese government)

Outline

- **Introduction of New CRL**
- **Ultra-HDR SatCom R&D Programs**
  - CRL's Gigabit Satellite technology R&D
  - NASDA / CRL's Gigabit Internet Test Satellite
- **Other Future Plans of R&D Satellites**
  - ETS-VIII (launch planned in 2003)
  - Quasi-Zenith Mobile SatCom System R&D
  - Optical Space Communications R&D

New CRL (Re-organized in April, 2001)

- **until Dec. 2000 : Research Organization under MPT**

Jan. 2001 : MPT --> MPHPT

- **from Apr. 2001 : National Research Organization as “Independent Administrative Instaitution”**
  - R&D of advanced communications technology
  - Contribution to industries and academia
  - Demonstration of applicability of advanced communication technology

Research Organization Structure in CRL (1)

- **Wireless Communications Division**
  - * Broadband Satellite Network G
  - * Optical Space Communications G
  - * Space Data Transmission G
  - * Kashima Space Research Center
    - Mobile Satellite Communications G
    - Space Cybernetics G
  - * Yokosuka Radio Communications Research Center
    - Wireless Innovation Systems G.
    - Broadband Wireless Access Systems G.
    - Mobile Communications G.
    - Millimeter-Wave Devices G.
    - Wireless Networks Integration G.
    - Electromagnetic Compatibility G.
    - Broadcasting Systems G.

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Research Organization Structure in CRL (2)

- **Information and Network Systems Division**
  - Next Generation Internet G
  - High-Speed Network G
  - Network Architecture G
  - Emergency Communications G
  - Keihanna Human Info-Communications Research Center
    - Human-Computer Intelligent Interaction G
    - Computational Linguistics G.
    - Interactive Communication Media and Contents G.
    - Social Interaction G.
    - Image G.
    - Nishida Synsophy Laboratory
- **Applied Research & Standard Divisions**
- **Basic and Advanced Research Division**

Background of Gigabit SatCom R&D

- **CRL's Gigabit Satellite Project [Origin]**
  - * 1992~ : Feasibility Study
  - * 1995~ : Development of key component technology
    - Scanning Spot Beam Antenna (Ka-band active phased array)
    - On-board ATM Switch (On-board MODEM, ATM Switch)
    - Network synchronization
  - * Conceptual Design of The Gigabit Satellite (FY1999)
    - CRL / NASDA joint team was formed in 1999.
    - Communication payload, satellite bus, launch vehicle selection was done.
- **Governmental Project for IT Revolution Promotion announced in FY2000**
  - * NASDA : High Speed Internet Infrastructure Utilizing Space Technology (i-Space)
  - * MPT : Space Internet Technology R&D
  - * "***Gigabit Satellite***" -> "***Gigabit Internet Test Satellite***" (working name)

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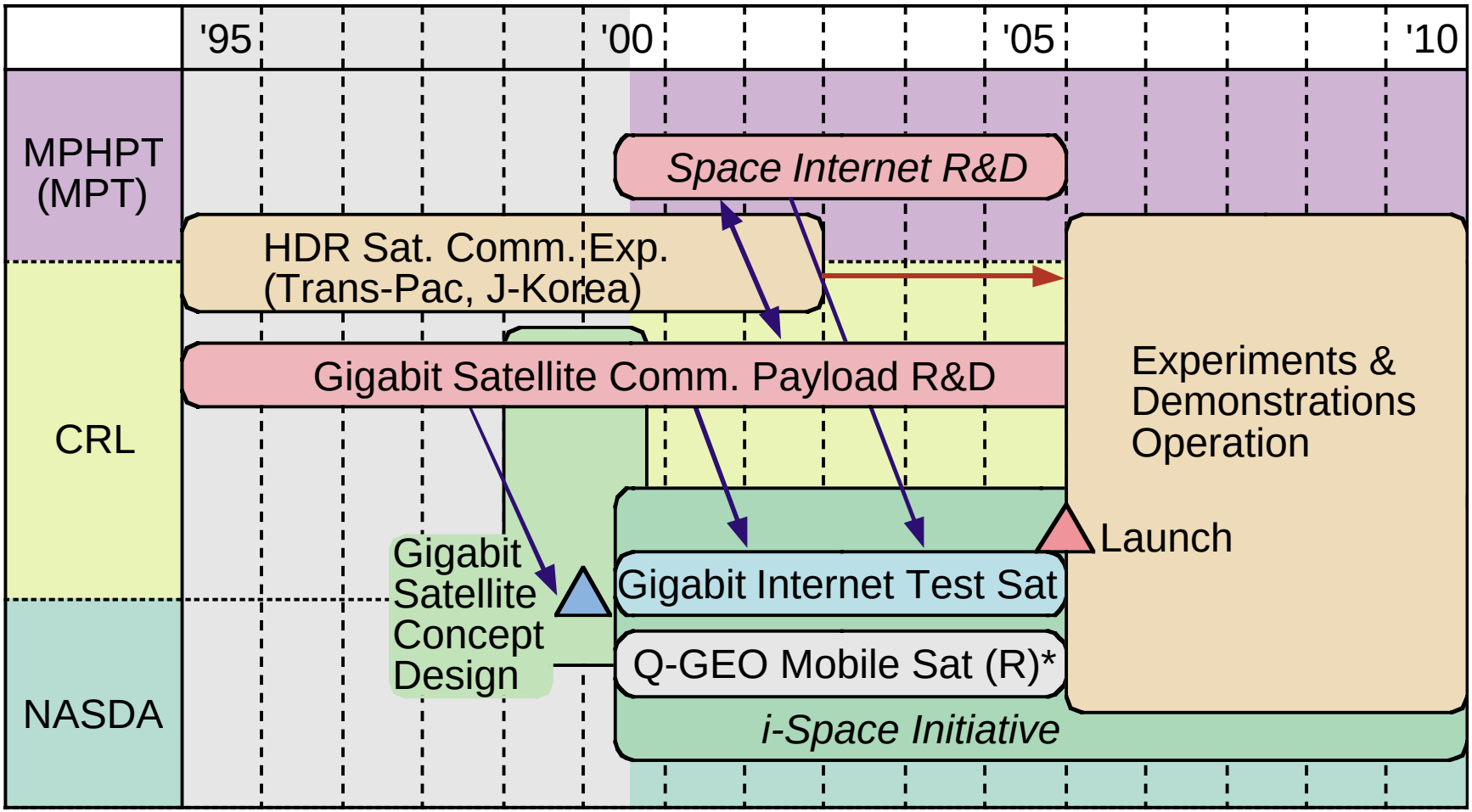
Experimental System Development Plan

- Space Internet / i-Space -



*Q-GEO Sat is planned only research

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Concept Design of The Gigabit Satellite(1)

Target Specification of Satellite System

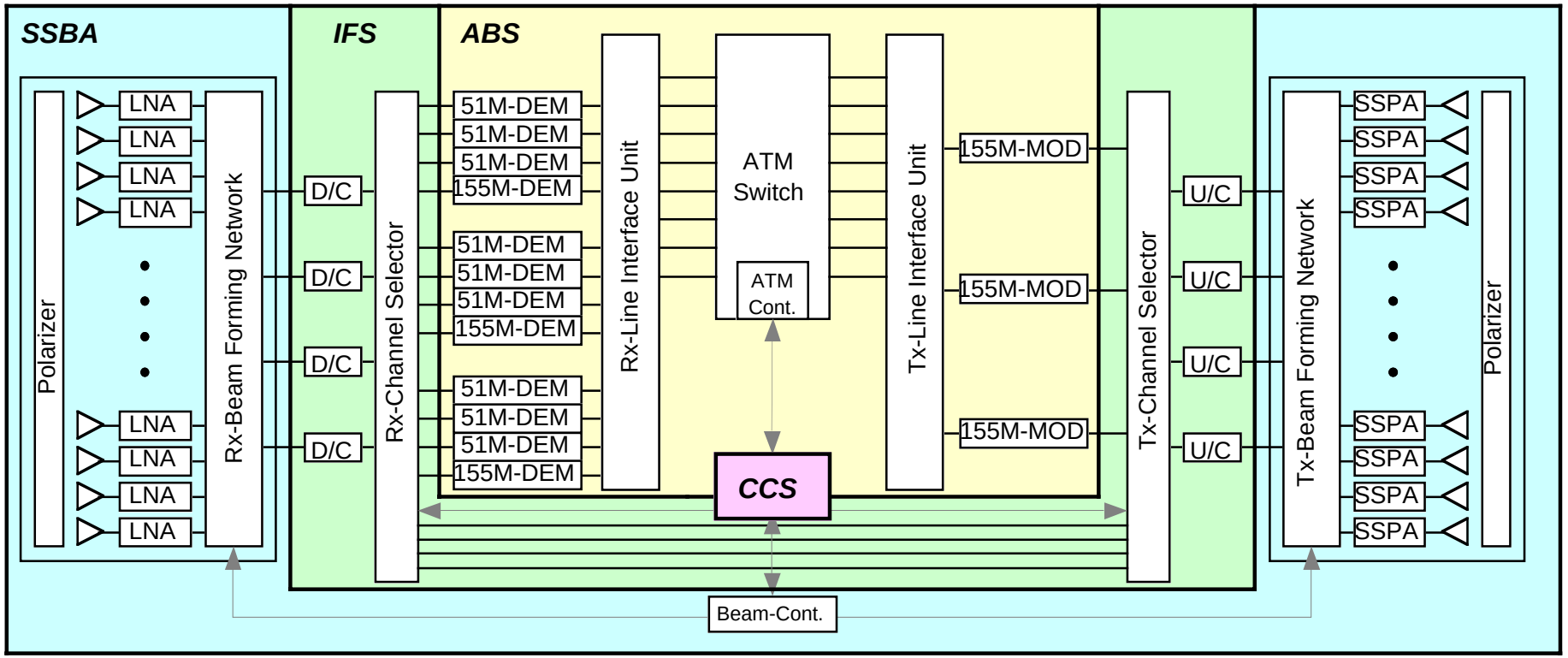
Shape	Rectangular body with deployable solar paddles
Target weight	2-ton class (BOL)
Attitude control	3 axis stabilized
Attitude control accuracy	Roll / Pitch : ± 0.05 deg. Yaw : ± 0.15 deg.
Life time	5 years
Electrical power	≥ 7.5 kW
Apogee engine	Thrust level : 500 N + 20 N
Ion engine	25 mN class (N-S manoeuvre)
Launch vehicle	H-IIA (5S Faring)
Launch site	Tanegashima space center
Assumed lauch date	2005
Orbit	GEO (146°E, 143°E or 154.5°E)
Station keeping	± 0.1°

Concept Design of The Gigabit Satellite(2)

Major Communications Specifications

Access Link	
Frequency	28.05 ± 0.55 GHz (up), 18.25 ± 0.55 GHz (down)
Type	Active phased array feed SSBA
No. of Beams	4
Scanning Angle	± 7 ~ 8°
Diameter	about 1.6 m (Up-link), about 2.4m (Down-link)
EIRP	≥ 71 dBW / beam
G/T	≥ 18.6 dB/K
On-Board Switching	
ATM Switching	Data Rate : 1.5~51Mbps / 155 Mbps (up) 155 Mbps (down) Throughput : ≥ 622 Mbps
IF Switching	Bandwidth:1.1 GHz Data Rate : ~ 1.2 Gbps

Configuration of The Payload



155M-DEM	: 155Mbps Demodulator	Beam-Cont.	: Beam Controller	LNA	: Low Noise Amplifier
155M-MOD	: 155Mbps Modulator	D/C	: Down Converter	SSPA	: Solid State Power Amplifier
51M-DEM	: 51Mbps Demodulator	U/C	: Up Converter		

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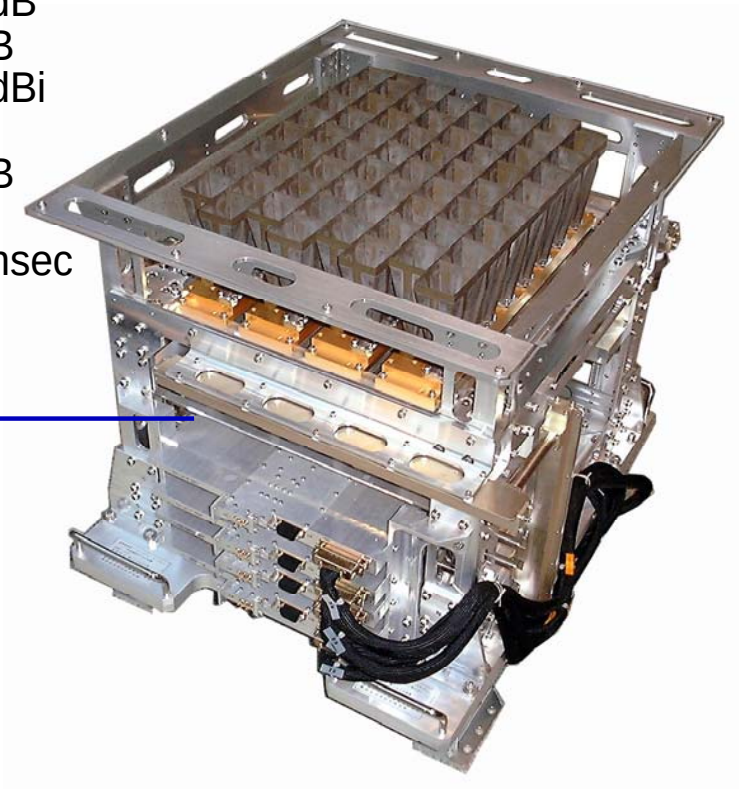
Distinguished Features of The Gigabit Sat

- **Wide area coverage by scanning beam capability.**
  - Most of Asia-Pacific area can be covered.
    (Orbit location has not been determined yet.)
- **Very wide bandwidth and powerful transponder.**
  - Bent-pipe mode. (Traditional connection scheme)
  - 1.1 GHz bandwidth.
  - EIRP : 71 dBW (per beams)
  - G/T : 18.6 dB/K
- **High speed regenerative transponder.**
  - ATM-based on-board switching function.
    - Terrestrial HDR network friendly.
  - Variable uplink transmission rate for various types of users.
    - 1.5 / 6 / 24 / 51.84 / 155.52 Mbps
  - Multiplexed down link.
    - 155.52 Mbps

BBM of SSBA (64 elements module)

	Tx Antenna	Rx Antenna
Frequency	18.25 ± 0.55 GHz	28.05 ± 0.55 GHz
No. of elements	64	64
Polarization	RHCP	RHCP
Input VSWR	≤ 1.49	≤ 6.1
Output VSWR	≤ 1.54	≤ 1.47
Freq. flatness	≤69.7°/5.9dBp-p	≤ 60.4°/7.2dBp-p
Interbeam isolation	≥ 58.4 dB	≥ 40 dB
Side lobe level	≥ 12.6 dB	≥ 11.1 dB
Axis ratio	≤ 1.4 dB	≤ 2.4 dB
Gain	≥ 32.4 dBi	≥ 32.4 dBi
Output power	≥ 69.5 dBm	NA
Noise figure	NA	≤ 5.0 dB
Power efficiency	≥ 13% (Lin.), ≥ 19.8% (Sat.)	NA
Delay deviation	≤ 2.45 nsec	≤ 1.29 nsec
Sprious	≥ 50 dBc	NA
IM	≥ 23.9 dB (2.5 dB back off)	NA
Consump. power	120 W	29.1 W



- **BBM development of 64 elements active phased array antenna in Ka-band was completed. (1998)**
- **Flight model :**
  - 38 units of 64 Elements module.

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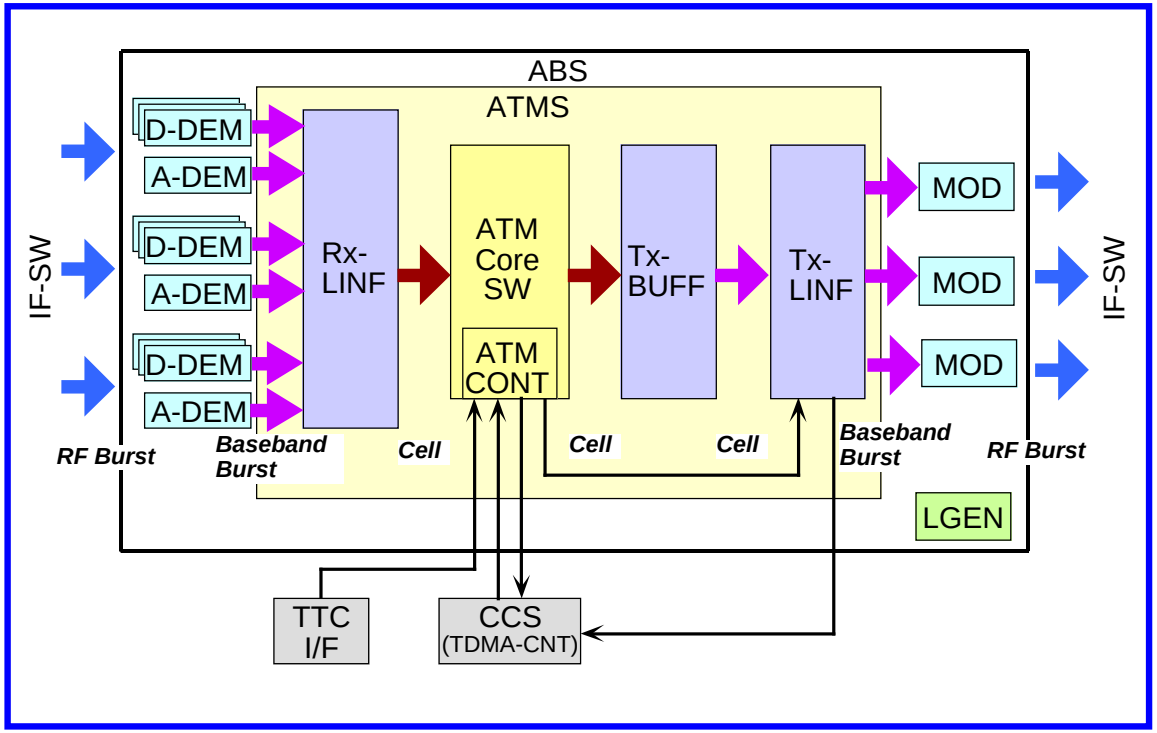
BBM of ABS (1)

- BBM of 51M-DEM and 155M-MOD was Developed. (FY1999)
- BBM of 155M-DEM is under development. (completion : June 2001)
- Subsystem BBM is under development. (completion : mid-2001)



Configuration

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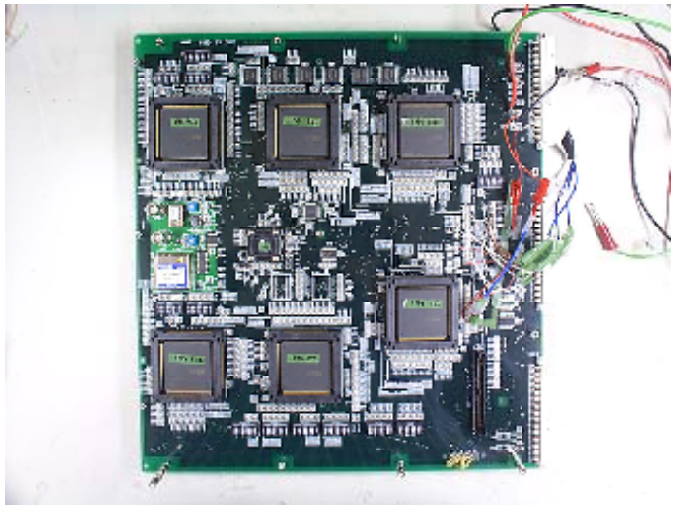
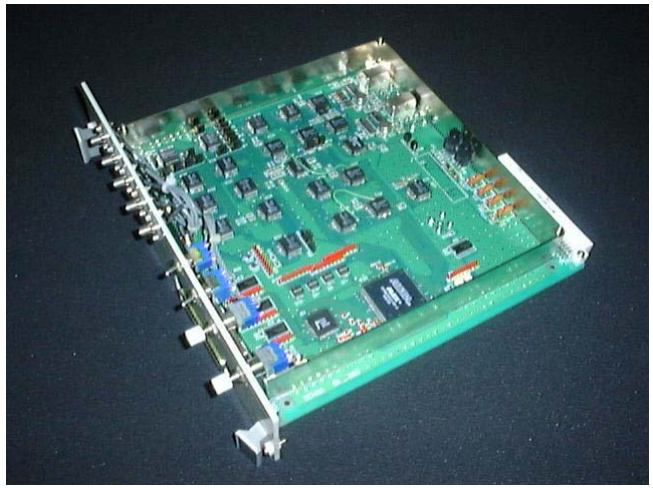
BBM of ABS (2)

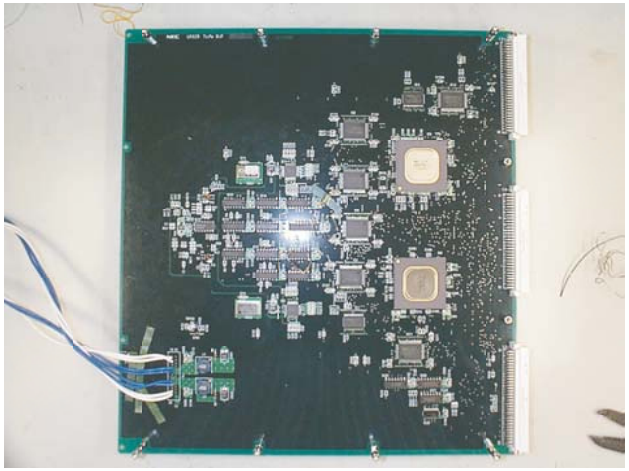
On-Board ATM Switch (BBM)



Switch-Core Board



Prototype of On-Board Demodulator



Line Interface Board

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Effectiveness of Satellite for HDR Internet

- **Advantageous features**
  - Wide area coverage.
  - Multicast / broadcast capability.
  - Rapid deployment of links for emergency / tentative use.
- **Effective solution against “Digital Divide”**
  - Cost effective way to cover large area with a satellite.
  - Rapid expansion of networks to remote areas.
- **Possibility of developing new type of services**
  - Interactive multimedia.
  - Multicast streaming.

Significance of R&D of The GITS

- **Bringing Technology Breakthrough to Satcom Area**
  - R&D of advanced and practical technology
    - Gigabit rate SatCom technology
    - On-board switching & routing for effective networking
    - Application demonstrations
- **Satcom in Total-Network (to meet the user's requirement)**
  - Roles of satellite in communication infrastructure
    - Wide area coverage, flexible connectivity, multimedia / multicast, asymmetric, etc.
  - Low cost and "Zero conf" terminal
  - Inter-operability with other networking technology

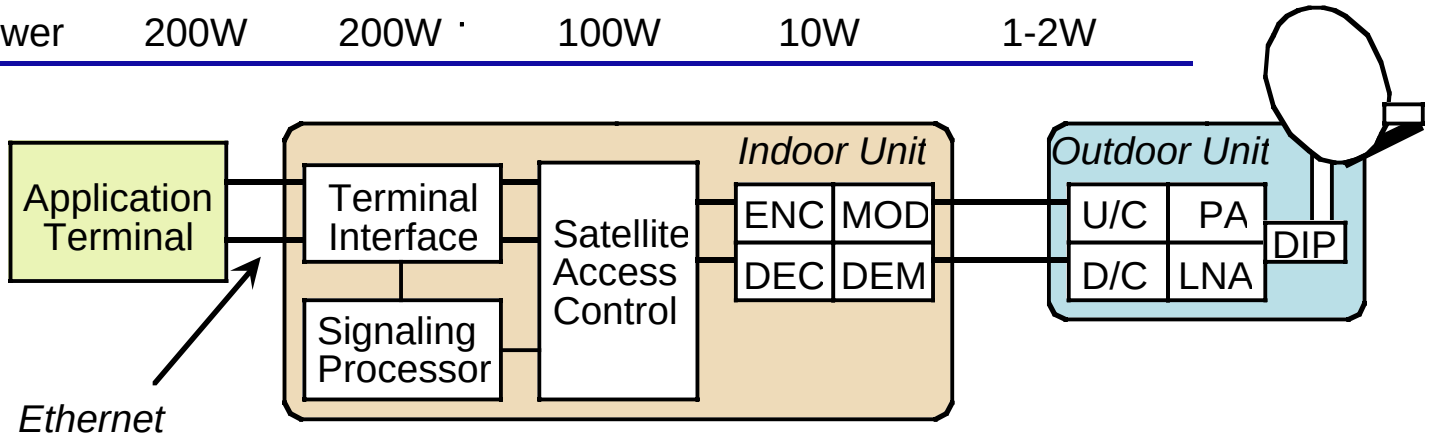
Basic Concept of Gigabit Internet Test Satellite

- **For Experimentation**
  - * Coverage : Asia Pacific
  - * Connection : Interactive, Multicast, etc.
  - * Terminal : 45 cmø - 5 mø
- **For Technology Development (Payload Design)**
  - * Gigabit Satellite Based
    - - High EIRP, G/T antenna configuration
      - ・ Multi-spot-beam, wider coverage.
    - - On-board switch / router
      - ・ Higher throughput, flexible connectivity.
  - * Internet friendly function
    - - Layer 2 switching function
    - - Layer 3 routing function
    - - IPv6 capability, etc.

Earth Station Configuration and Functions

Types of Earth Stations

Type	Hub	SDR-VSAT	HDR-VSAT	USAT-S	USAT-C
Frequency	U/L 28.05GHz±0.55GHz（TBD）				
	D/L 18.25GHz±0.55GHz（TBD）				
Trans. Rate	U/L 1.2G	U/L 622M	U/L 155M	U/L 6M	U/L 1.5M
(bps)	D/L 1.2G	D/L 622M	D/L 155M	D/L 155M	D/L 155M
Ant. Diameter	5m	2.4m	1.2m	0.66m	0.45m
Tx Power	200W	200W	100W	10W	1-2W



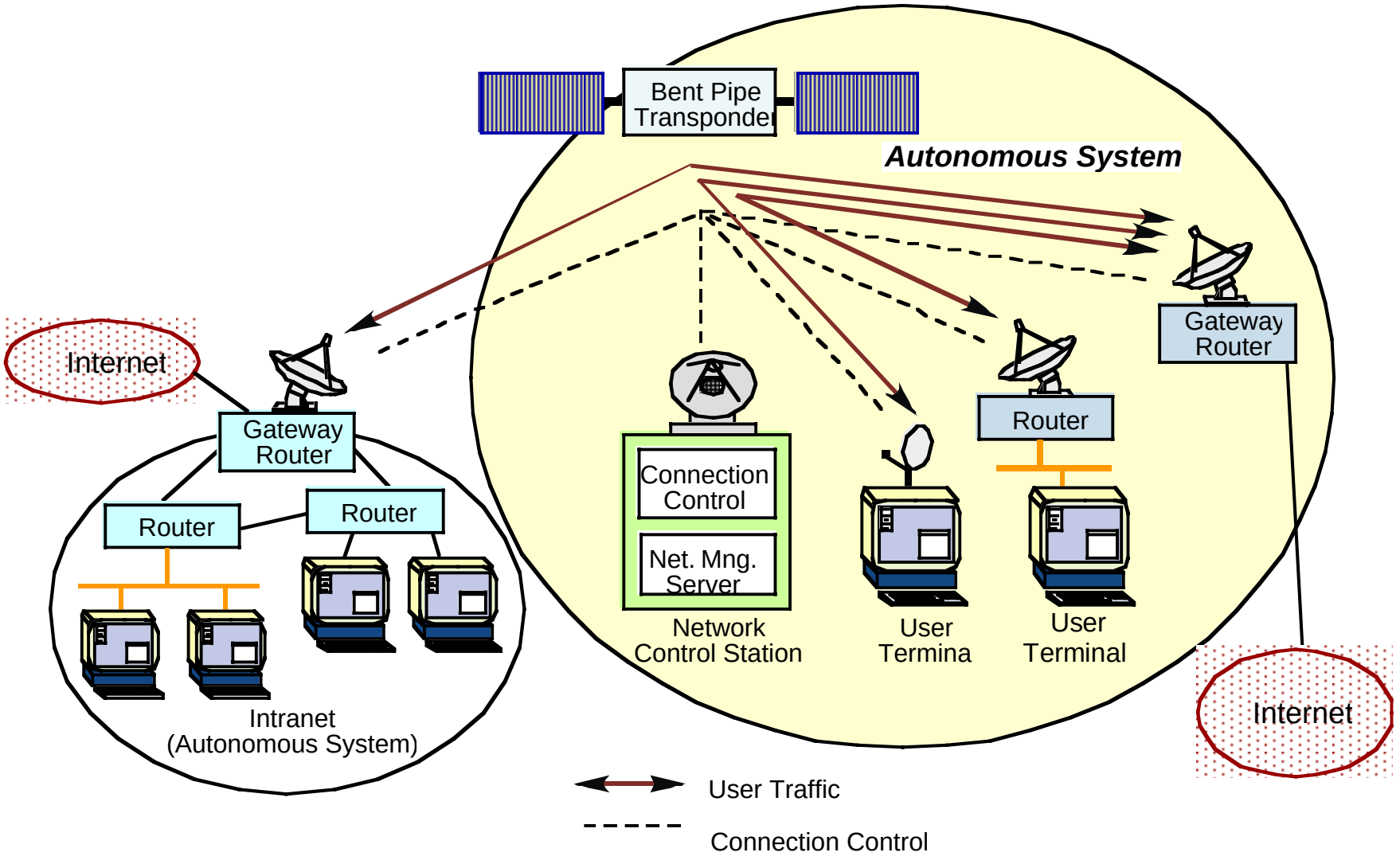
- Multiple Access Control
- Network Synchronization Control
- Network Management and Monitoring
- Transponder Configuration Management
- Rain Attenuation Compensation

Issues for Space-Based Internet

- **Network Architecture**
- **Protocol Issues**
  - * Air Interface
  - * IP Routing Schemes
  - * TCP/IP Handling
    - - TCP Extension
    - - Performance Enhancement Proxy
    - - IPv6
- **Standard Issue**
  - * IETF, ETSI, ITU-T(SG-13) /-R(SG-4B)
  - * CRL / MPHPT Activity in Japan

Networking Architecture

- Bent-Pipe Transponder -



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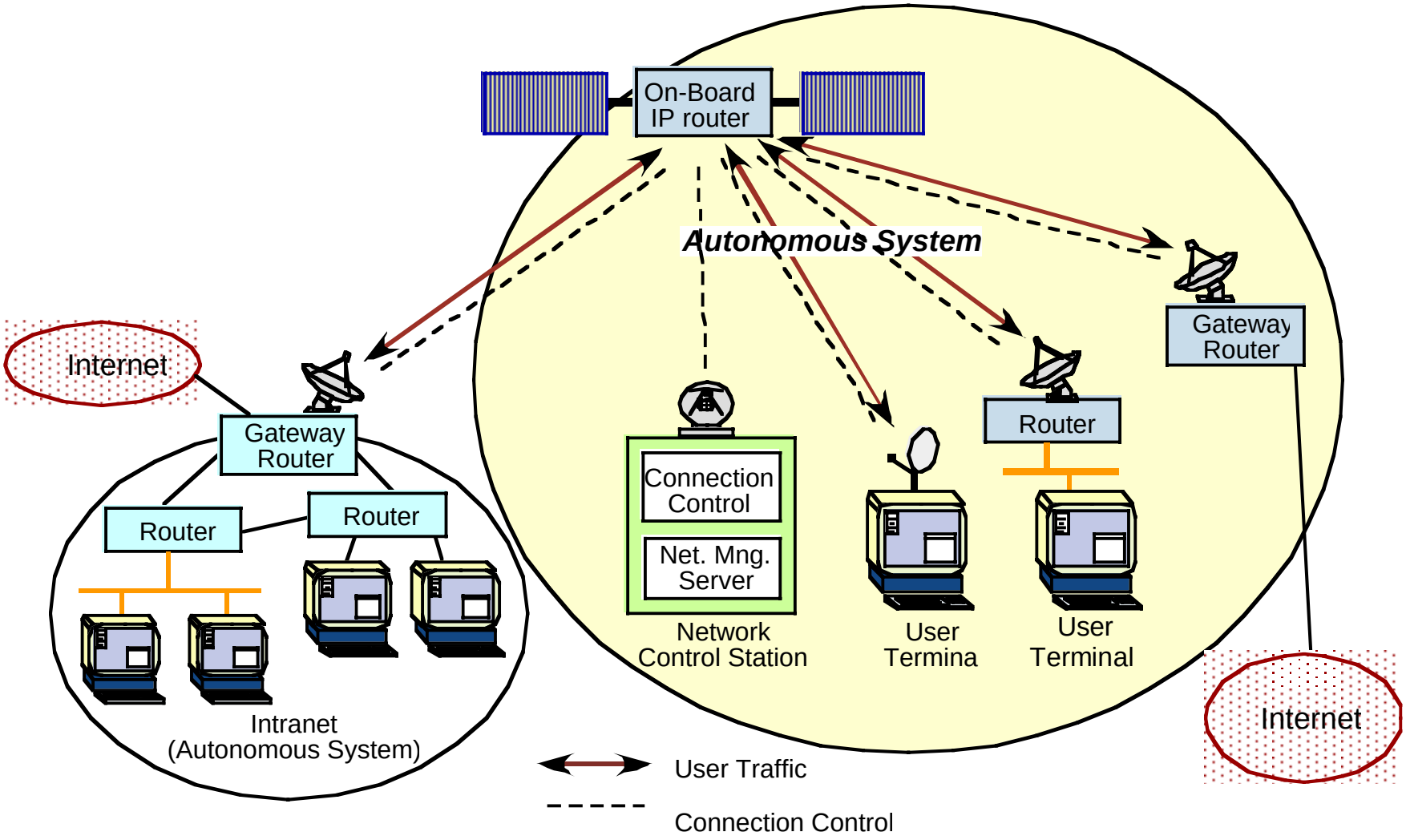
Networking Architecture

- On-Board Switch / Router -



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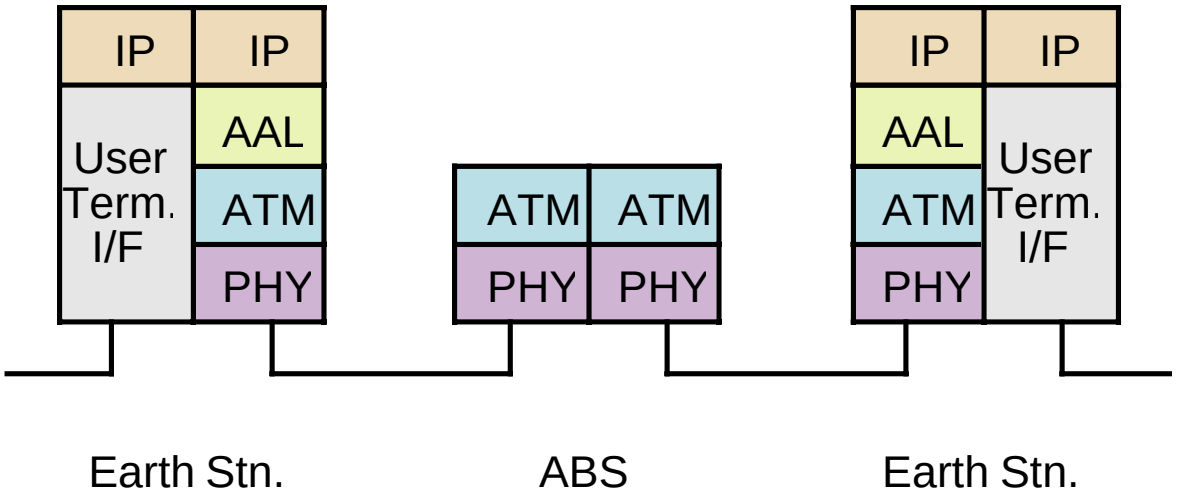
Considerations of Protocol

- **Multiple Access Scheme / Synchronization**
  - Multi-beam operation for HDR transmission
- **Modulation / Coding**
  - Power efficiency / Frequency efficiency
- **Framing Structure**
  - Framing efficiency, flexibility
- **Layer 2 Switching : ATM-based**
  - Very high throughput
  - Various service classes
  - QoS management
- **Layer 3 Routing**
  - Software-based technology
  - Flexible, but complicated
  - New technology appears in a short period.

Space-Based IP Routing Scheme (1)

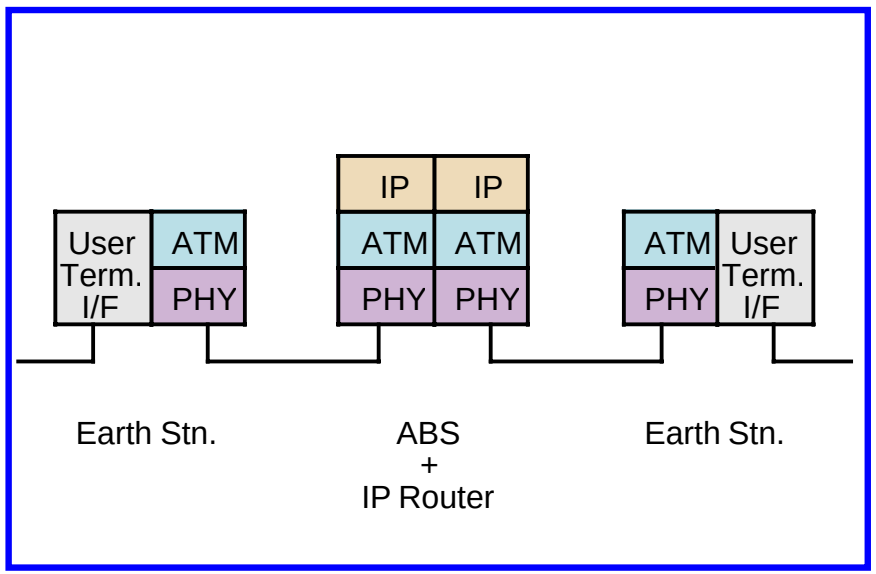
Classical IP over ATM



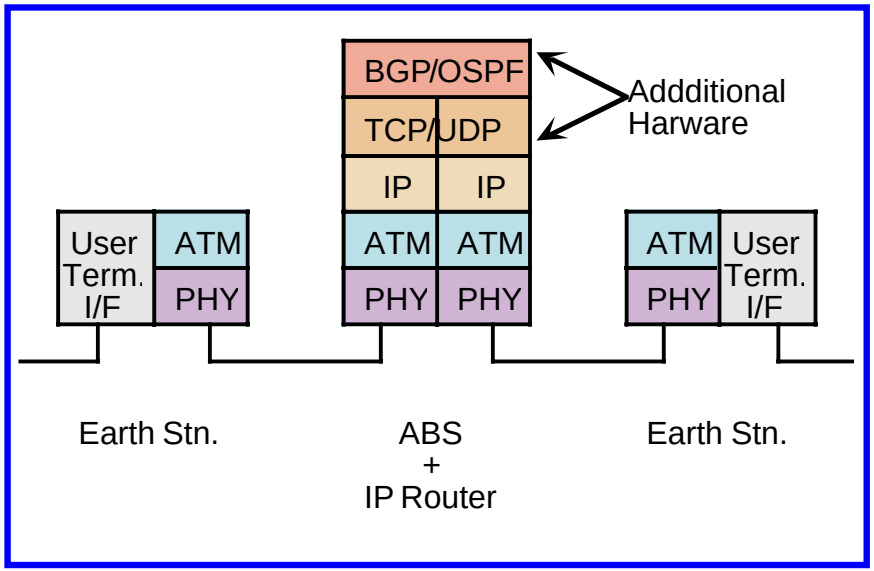
- IP Layer @ Earth station
- PVC-based connection required.
- No additional software / hardware required.
- MPoA is not feasible for future application.

Space-Based IP Routing Scheme (2)

On-Board IP Router



Case-1

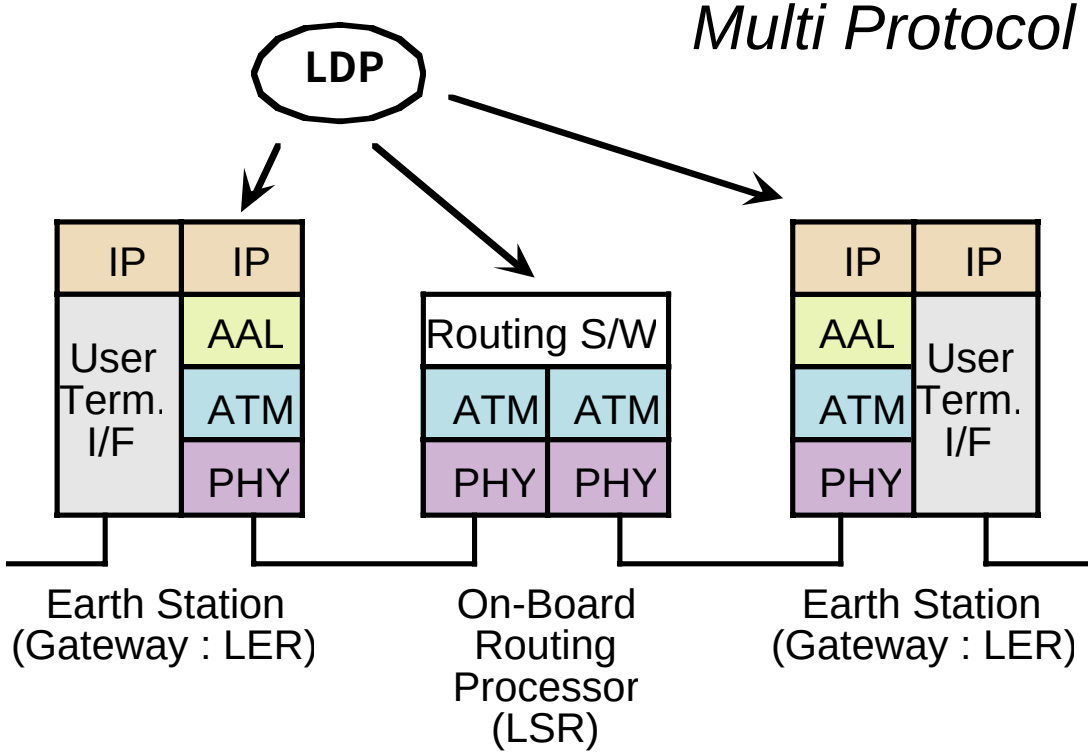


Case-2

- IP Layer @ Satellite
- Additional software / hardware required.

Space-Based IP Routing Scheme (3)

Multi Protocol Label Switching



- Label Distribution Protocol (LDP) required in Earth station and On-Board ATM Switch (software).
- MPLS Applied.
  - Earth station : Label Edge Router
  - ABS : Label Switched Path operation.

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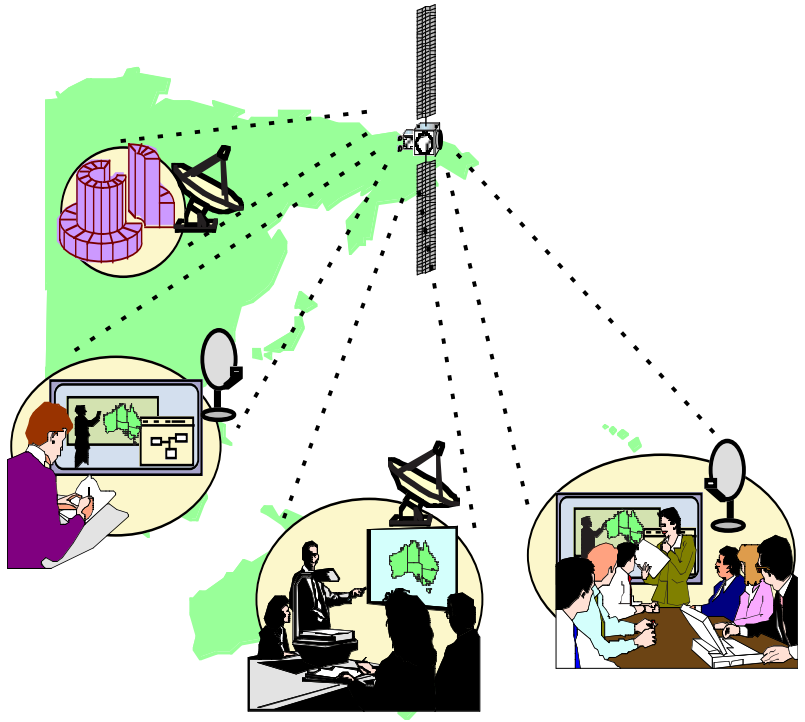
Application Demonstrations with GITS

Objectives :

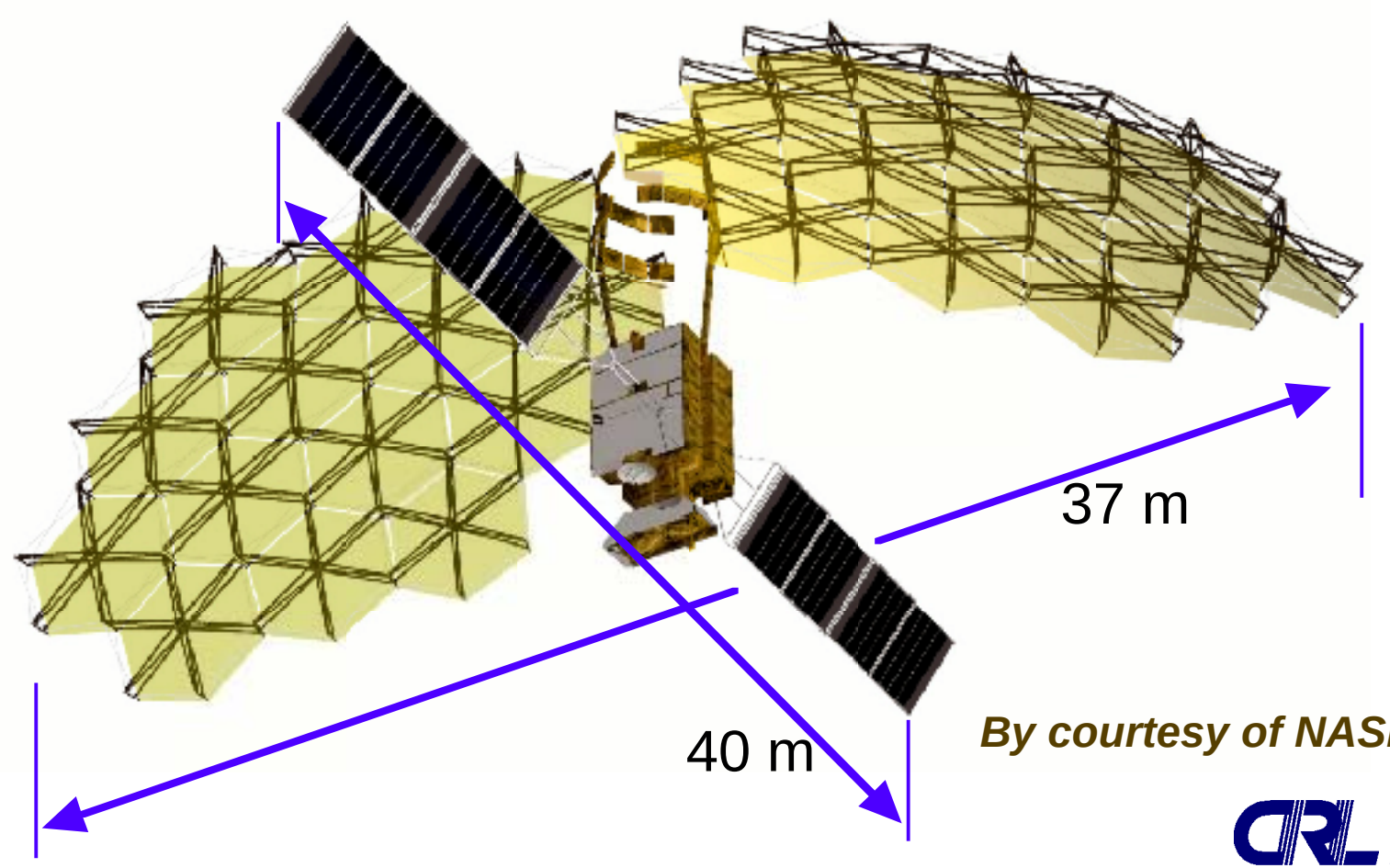
Demonstration of advanced communication technologies
Development of new types of applications
Promotion of international joint experiments

- **Gigabit network applications**
  - * Large-scale distributed databases
  - * Distributed super-computing
  - * etc.
- **HDR multimedia applications**
  - * Tele-Medicine, Home Care, Distance Learning by High Definition Video
  - * High Speed Internet Access
  - * etc.



ETS-VIII Project

- **Main missions**
  - * Advanced 3-ton class bus
  - * Large-scale deployable dish
  - * Advanced mobile satcom and broadcasting
  - * Fundamental technology for positioning



By courtesy of NASDA

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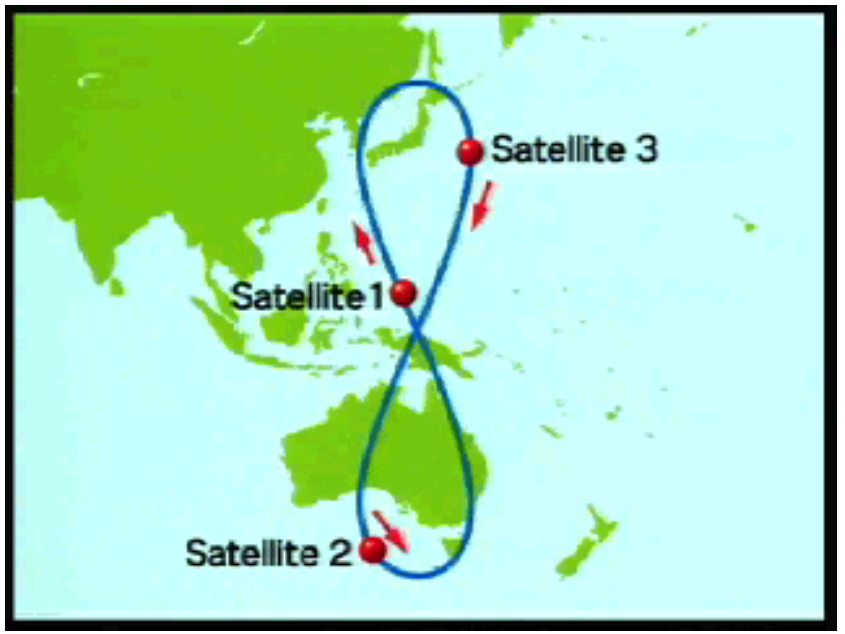
Outline of ETS-VIII

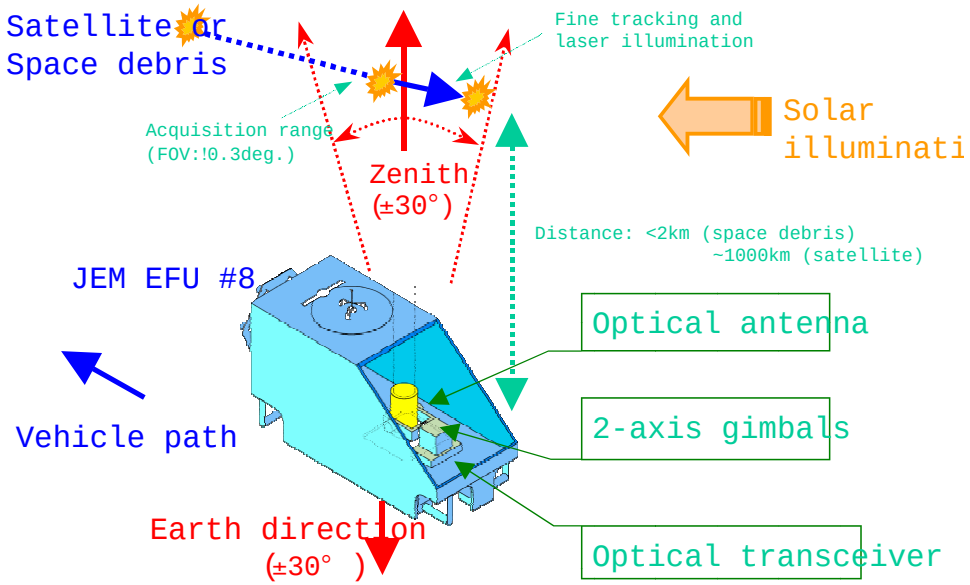
Launch plan :	2003 by H-IIA to 146°E (GEO)
Weight on orbit :	2,900kg(Sat. at BOL), 1,200kg (Payload)
Attitude Control :	3-axis-stabilized
Design Life :	10 years (Bus), 3 years (Mission)
Electrical Power :	7,500W (after 3 years)
Large-Scale Ant. :	19 m x 17 m Active phased array fed (31 elements) 400 W RF Power
Transponder :	OBP (Packet-SW / Circuit-SW) Bent-pipe mode
Positioning :	On-board atomic clock, time comparison equipment

Quasi-Zenith Satellite System for Mobile Satcom

- “EFSAT” (Eight-Figure SATellite) in geo-synchronous circular orbits with inclination around 45 deg.
- Suitable to regional land-mobile communication services in middle latitudes
- Minimum elevation angles as high as 70 deg.
- HDR mobile communications services
- Mainland Japan and the South-Eastern populated areas of Australia.

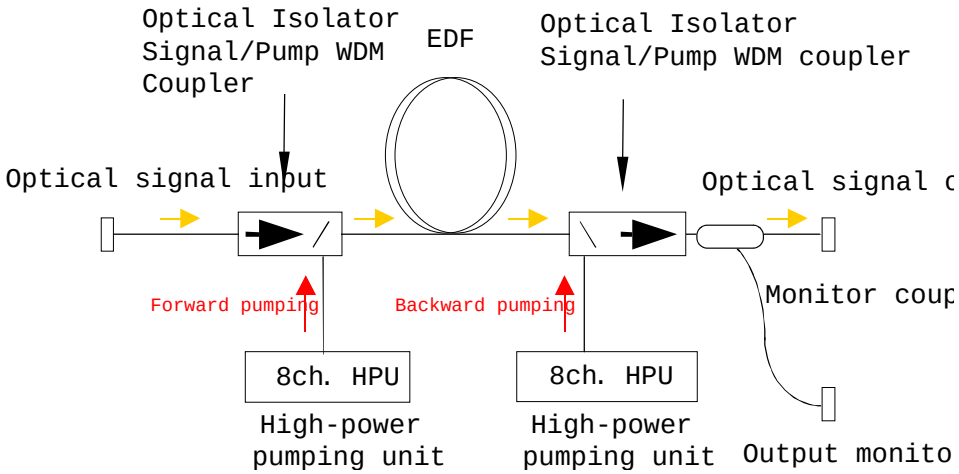


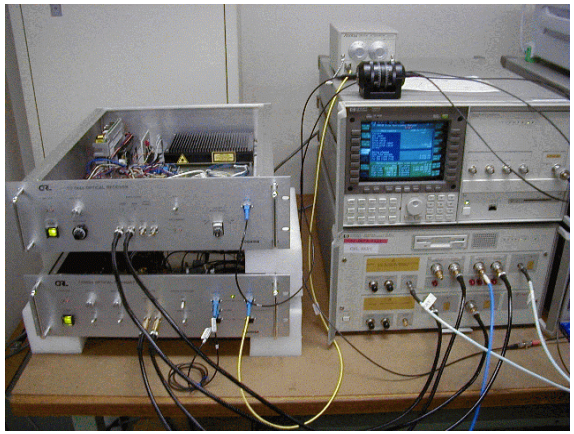
Laser Communications Demonstration Experiment(LCDE)



Tracking of Geodesic Satellties and Debris from ISS

Antenna type	Coaxial Cassegrain telescope, Diameter: 15cm
Transmit-rate	2.48832Gbps
Modulation	Intensity modulation with Return to Zero pulses
Demodulation	Direct detection with a polarization-maintaining EDFA
Communication wavelength	1.552micron(transmit), 1.562micron(receive)
Transmit power	400mW(CW, at the high power EDFA output)
Rx sensitivity	90photons/bit(BER:10-9)
Power cons.	Less than 115W (mission equipment)
Weight	Less than 90kg(mission equipment)





High Power Er-Doped Fiber Amplifire

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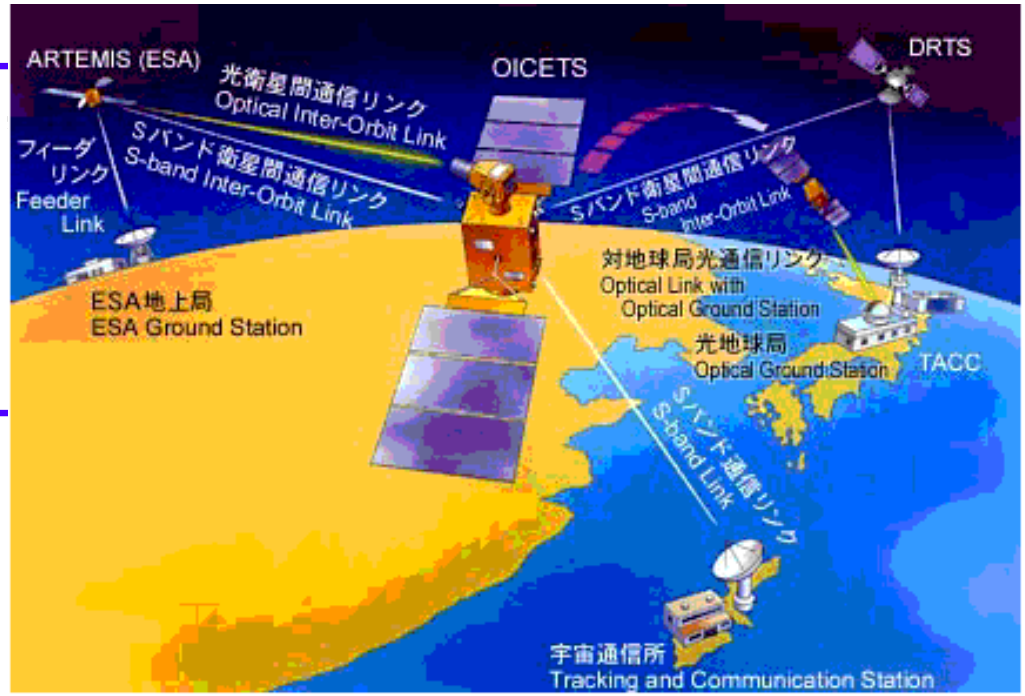
Optical Inter-orbit Communications Experiment with ESA

- **Optical Inter-orbit Communications Engineering Test Satellite [OICETS]**
  - * Between OICETS and ESA's ARTEMIS
  - * Light beam acquisition.
  - * Tracking and directional control for optical inter-satellite communications.

Orbit altitude:	610 km (BOL) 550 km (EOL)
Orbit inclination:	35 deg.
Weight:	570 kg
Mission duration:	One year



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Conclusions

- **Technology R&D for Space-Based HDR Internet**
  - * Expected as an effective way to expand high quality Internet and an attractive platform for new type of services.
  - * Gigabit Satellite Concept
    --> *Gigabit Internet Test Satellite* (2005)
    - High EIRP&G/T multi-spot-beam antenna
    - High throughput on-board switch / router
    - Network architecture
    - Simply operable ground segment
    - Demonstration of various types of applications
- **Other Projects for Next-Generation Satcom R&D**
  - * Advanced mobile satcom R&D
    - ETS-VIII (2003) / Quasi-Zenith Satellites
  - * Optical space Communication technology R&D
    - LCDE / OICETS

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