Network Upgrade of GALAXY Project

Kazunori Kumagai and Hisao Uose
Service Integration Laboratories
Nippon Telegraph and Telephone Corporation
Tokyo, Japan

kumagai.kazunori@lab.ntt.co.jp, uose.hisao@lab.ntt.co.jp

GALAXY: Japanese e-VLBI Research Team

- Members
  - NTT Laboratories, Communications Research Laboratory (CRL), National Astronomical Observatory of Japan (NAOJ), Institute of Space and Astronautical Science (ISAS), Yamaguchi University and Gifu University
  - Collaboration with Super-SINET (NII) and Internet2®
- Targets
  - R&D of "(Quasi) Real-time VLBI" observation system
  - Scientific observation using the developed system
- Network Resources
  - Dedicated OC-48 (2.4Gb/s) network spanning larger metropolitan Tokyo area connecting radio telescopes and research centers (Both IP and ATM)
  - NTT's R&D network (GEMnet) providing connectivity to SINET and R&E networks outside Japan through Abilene and AMPATH
  - New WDM equipment including OXCs are being introduced
  - High-quality video conference systems
  - High performance PC arrays and Data storage

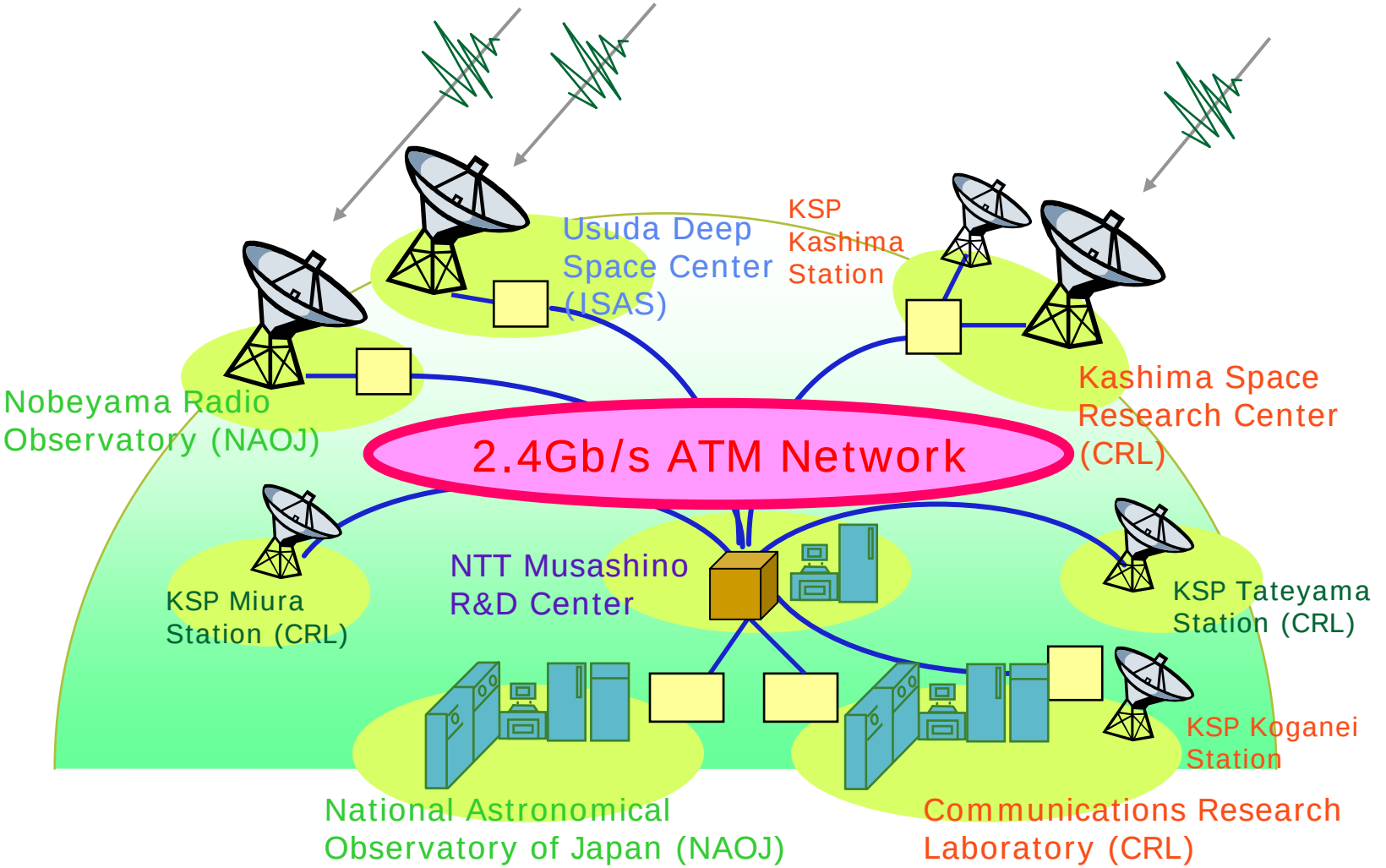
Recent Development

- System Development
  - Ultra High Speed Real-time System — NAOJ, CRL
    - 2Gbps ATM data transfer system, 2Gbps sampler, correlator systems
  - IP system (Real-time and Near-real-time) — CRL, NTT
    - PC-VLBI board and multi-stream IP data transfer system
  - PC-based Software Correlator — CRL

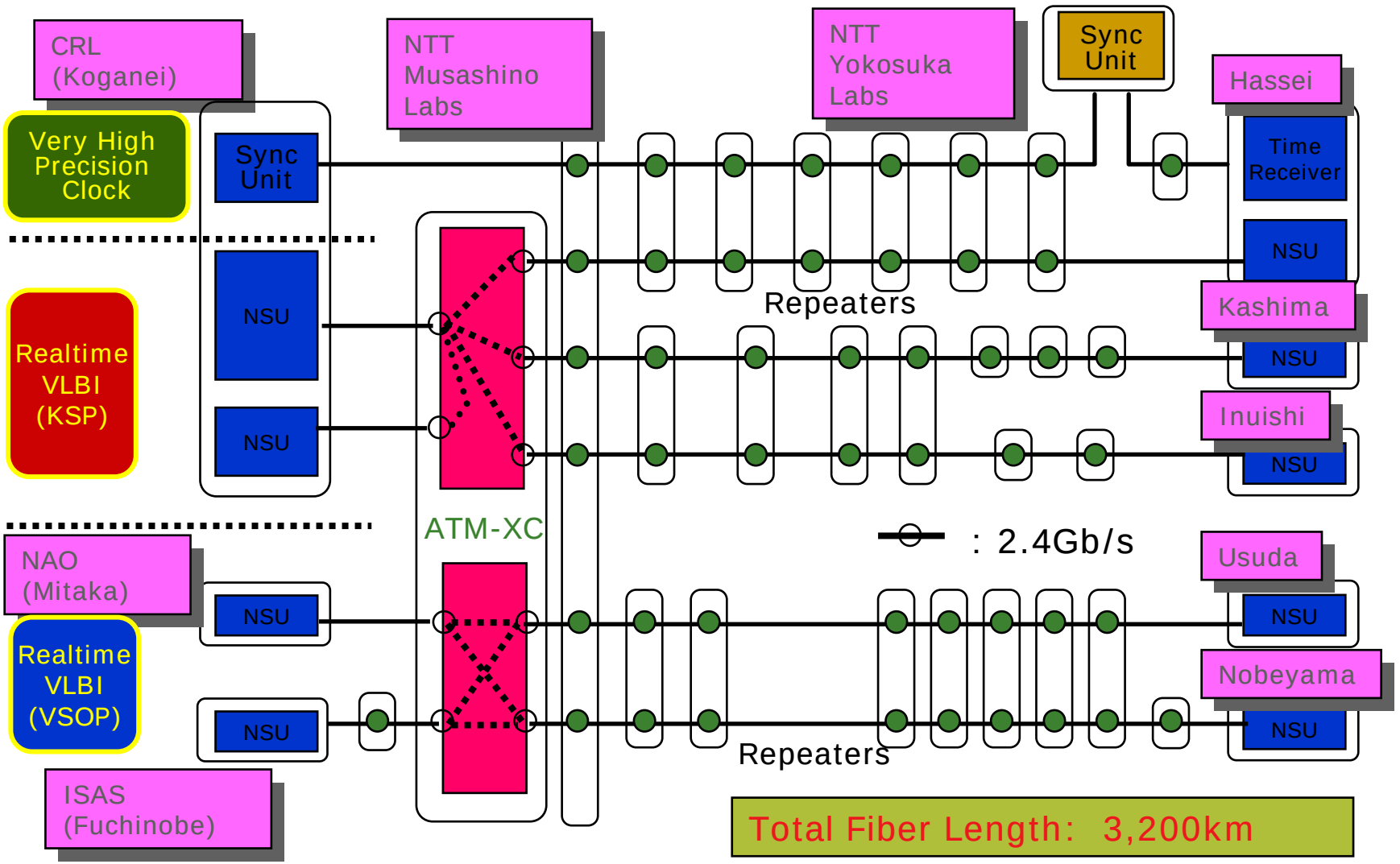
- Observation
  - Fixed beam survey with 4Gbps system — NAOJ
  - First international e-VLBI observation with MIT Haystack — CRL
  - Precise orbit determination of Nozomi satellite with PC-VLBI system
    ISAS, NAOJ, CRL, Yamaguchi U., Gifi U.

- Network Upgrades — NTT
  - More IP equipment
  - Connection to Super-SINET
  - New DWDM/CWDM connections under construction
  - Installation of large volume data storage (1.2TB)
  - Installation of video conference systems (MPEG2 & H.323)

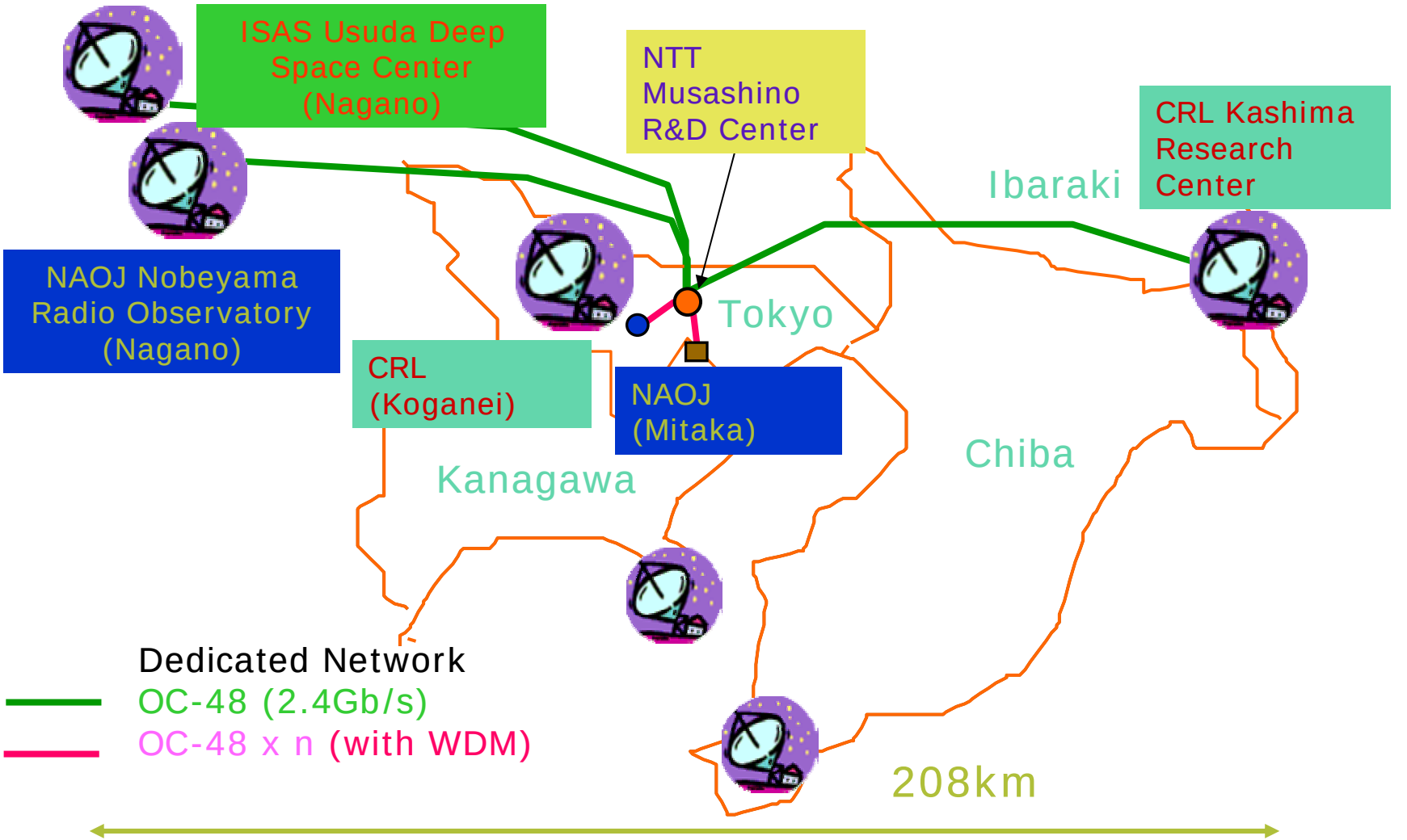
GALAXY/KSP Network dedicated for realtime VLBI (Pase1: 1996~1998)



Physical Configuration (Phase1: 1996~1998)



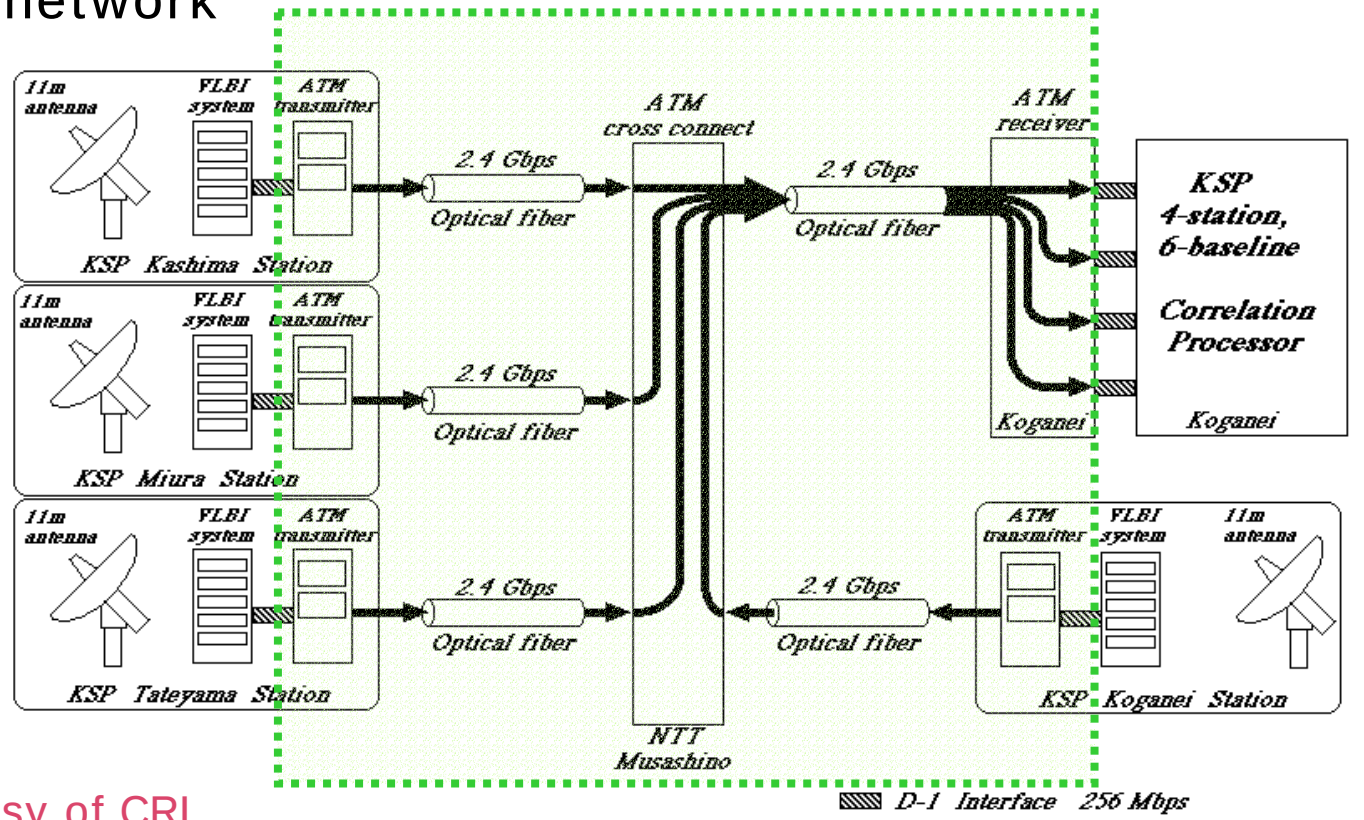
GALAXY/KSP Network: Geographical View



Realtime VLBI over ATM

Key Stone Project (1993-2001)

- 2.488 Gbps STM-16/OC-48 connection to 4 sites
- K4 data recorder was transparently replaced by the network

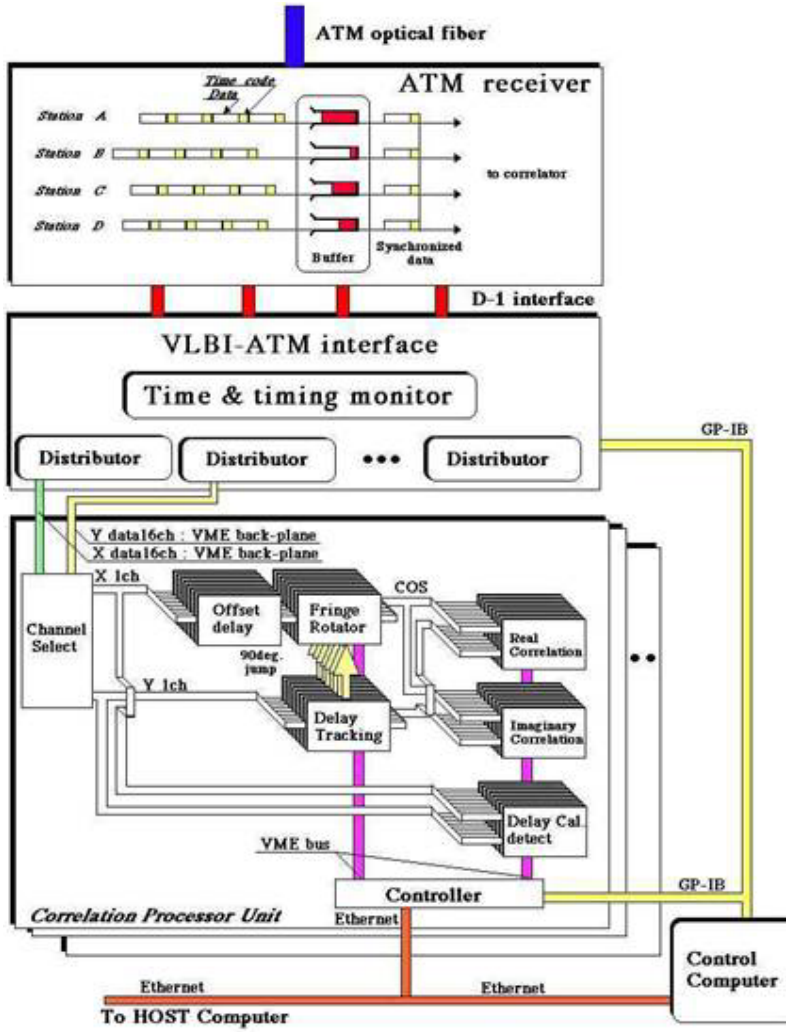


Courtesy of CRL

Real-time VLBI System used in KSP (1996~)

ATM receiver
+
VLBI ATM interface

Correlator

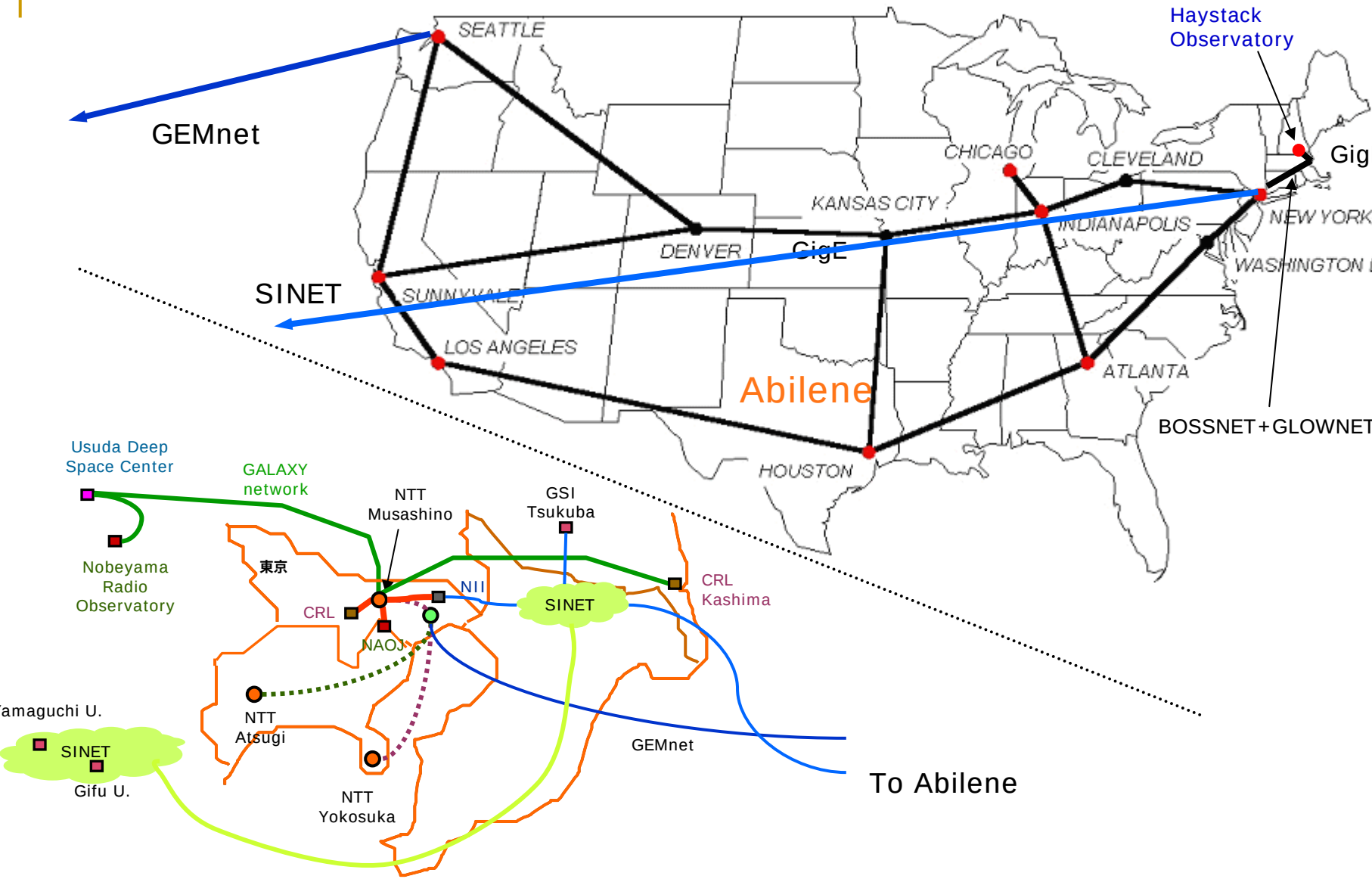


Courtesy of CRL

Network Upgrades (or downgrades)

- Physical Connections
  - Some long-haul links had to be abolished due to financial reasons
  - Connected to Super-SINET (2002)
    - Raw SDH links (2.4Gb/s) and direct IP peering with OC-12
  - We've started installing DWDM/CWDM network among NTT R&D centers and NAOJ, CRL
- Transport Technologies
  - We are upgrading IP portion of GALXY
  - But maintain ATM part for flexible use of the bandwidth
  - "Wavelength on demand" coming in the sight
- International connections
  - GEMnet trans-Pacific link has been upgraded to OC-3 (to Pacific Wave & Abilene) yesterday!!
  - SINET offers us ~300Mb/s for international experiments
  - New link from NY to Starlight (OC-12) due this month
- Network Applications
  - Large data storage for PC-VLBI observation data
  - High-quality video conference system

GALAXY and other Research Networks



Antennas Used for our Experiments

ISAS Usuda 64m

NAOJ Nobeyama 45m

CRL Kashima 34m

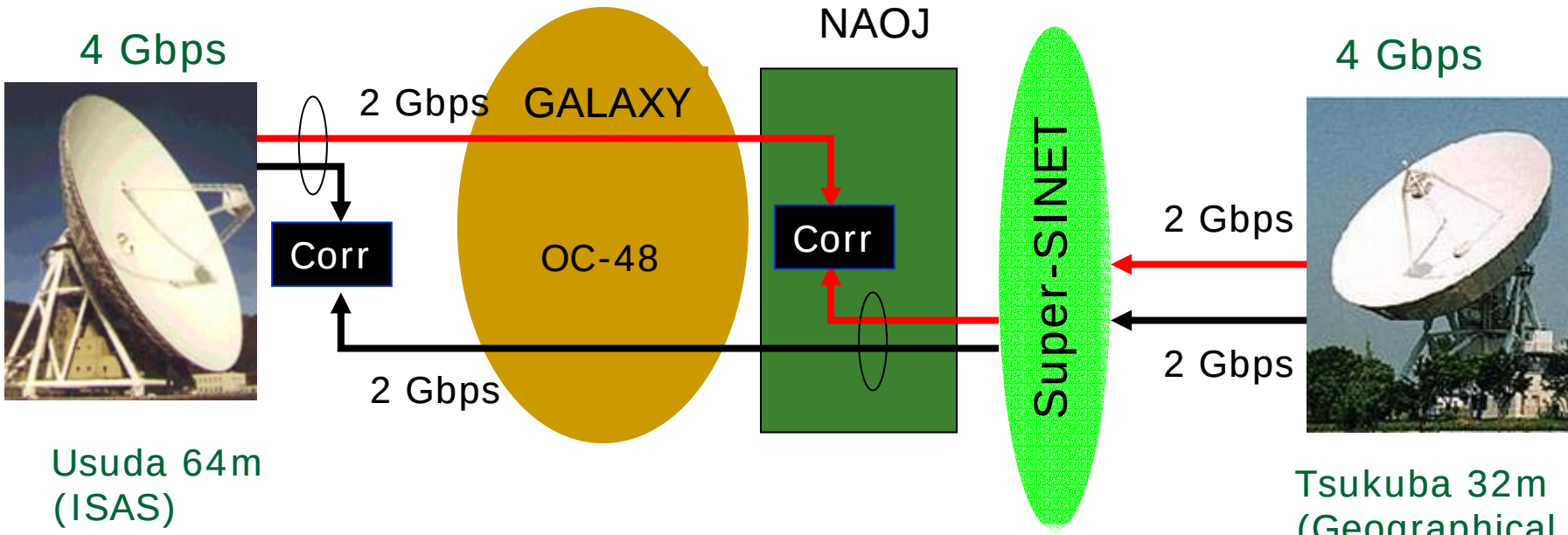
Former KSP 11m antennas
(Koganei, Kashima, Gifu, Chitose)

Recent additions

- Yamaguchi Univ. 32m donated by KDDI
- Tsukuba GSI 32m antenna

4Gbps Real-time Experiment (Dec, 2002)

- Data processing using two distributed correlators with the total throughput of 4Gbps

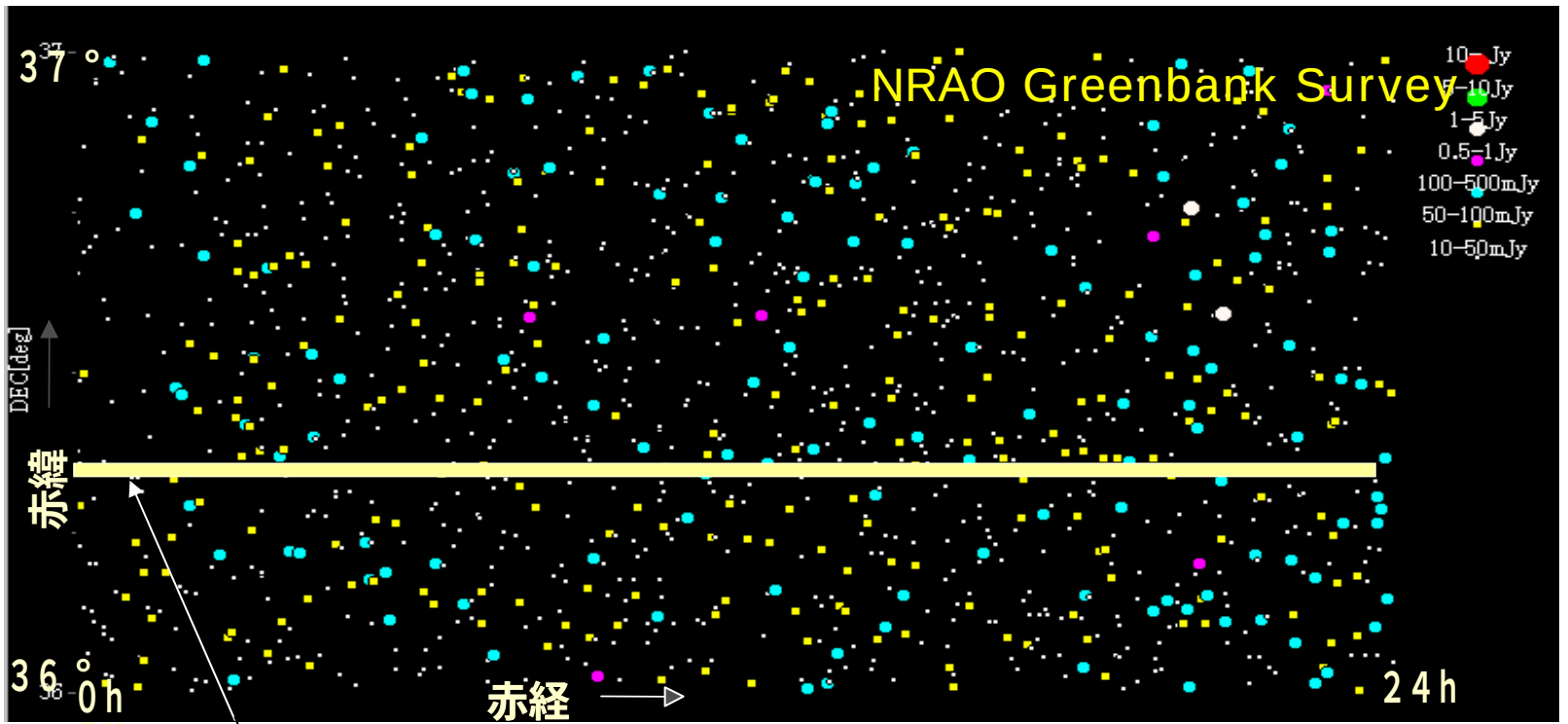


- We plan to add the third antenna to achieve 6Gbps observation this year

Courtesy of NAOJ

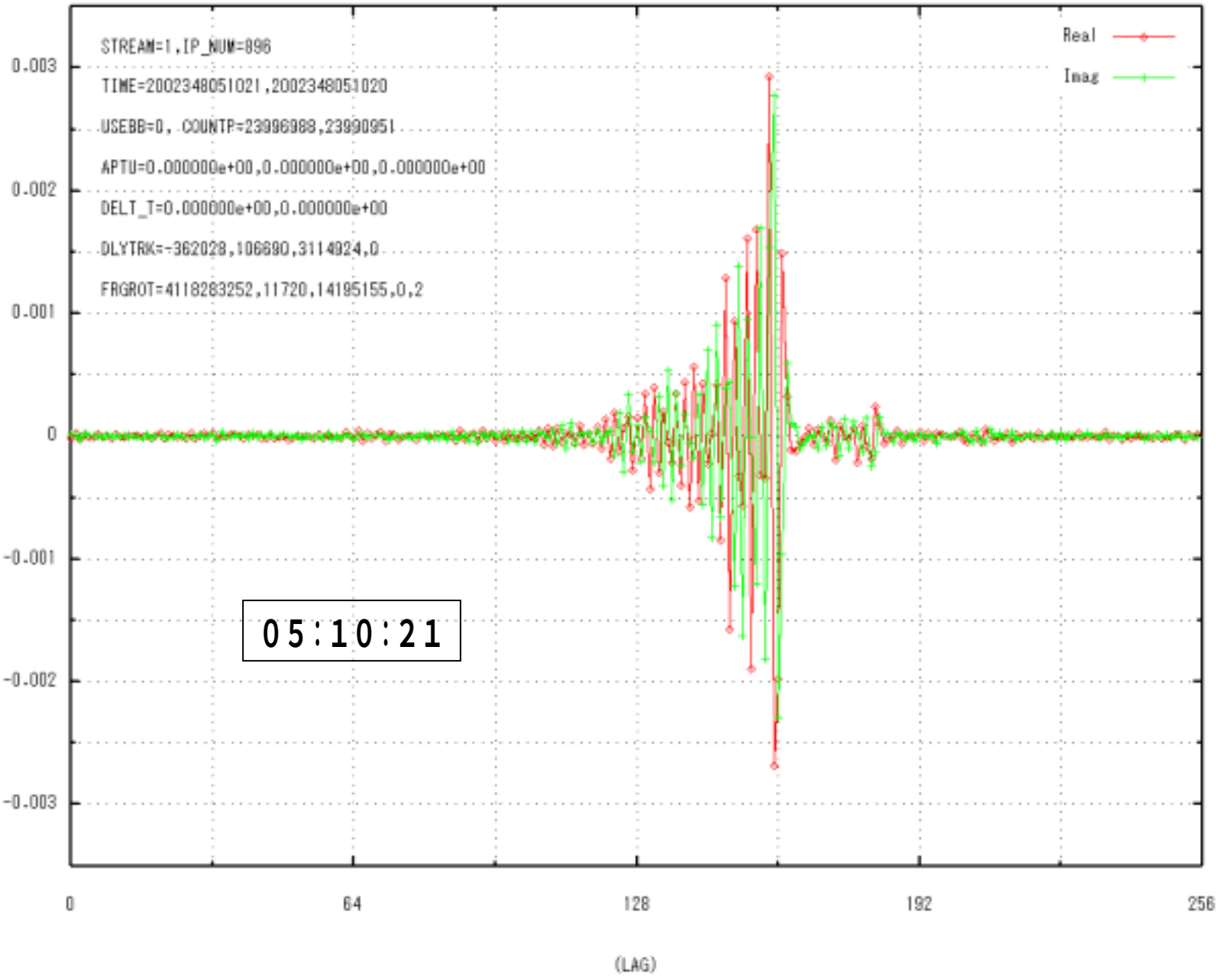
Fixed Beam Survey using 4Gbps System

- Use of idle Antenna time in each weekend
- 25 weeks of observations will cover the whole region of the figure



Beam Trace of Usuda 64m antenna (0.04 degree)

Courtesy of NAOJ


STREAM=1,IP_NUM=896
TIME=2002348051021,2002348051020
USEBB=0, COUNTP=23996988,23990951
APTU=0.000000e+00,0.000000e+00,0.000000e+00
DELT_T=0.000000e+00,0.000000e+00
DLYTRK=-362028,106690,3114924,0
FRGROT=4118283252,11720,14195155,0,2
Real
Imag
0.003
0.002
0.001
0
-0.001
-0.002
-0.003
05:10:21
0
64
128
192
256
(LAG)

IP Technologies for e-VLBI

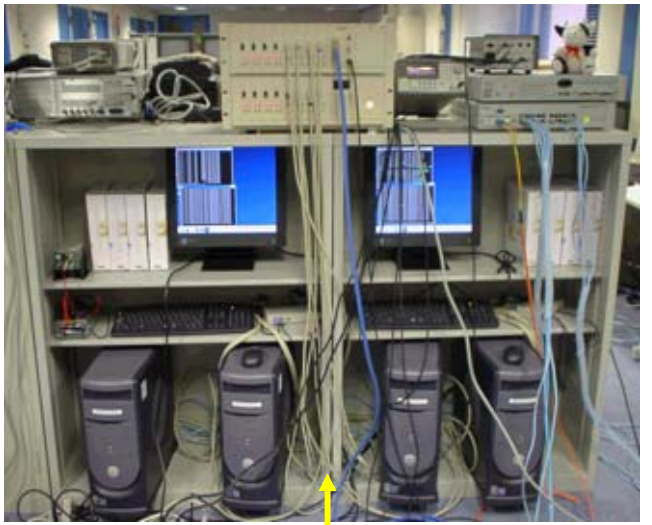
- Advantages
  - Utilization of “off-the-shelf” equipment
    - PCs, GbE routers, L2 switches, High-speed I/Os, etc...
  - Existing resources (R&E networks with vast BW)
    - Sharing resources with other BW eating applications
  - Improved connectivity with other observation sites
    - Using longer baseline becomes easier
    - Available antenna selection will be wider
  - Compatibility to distributed processing schemes and flexible data retrieval / mining schemes
- Disadvantages
  - Hard to guarantee quality of service
  - Complicated processing (error control, realignment of data packets etc.) necessary

Many challenging issues exist for communications carriers

The rationale for us (at NTT) to continue this project

IP VLBI data transfer system (NTT)

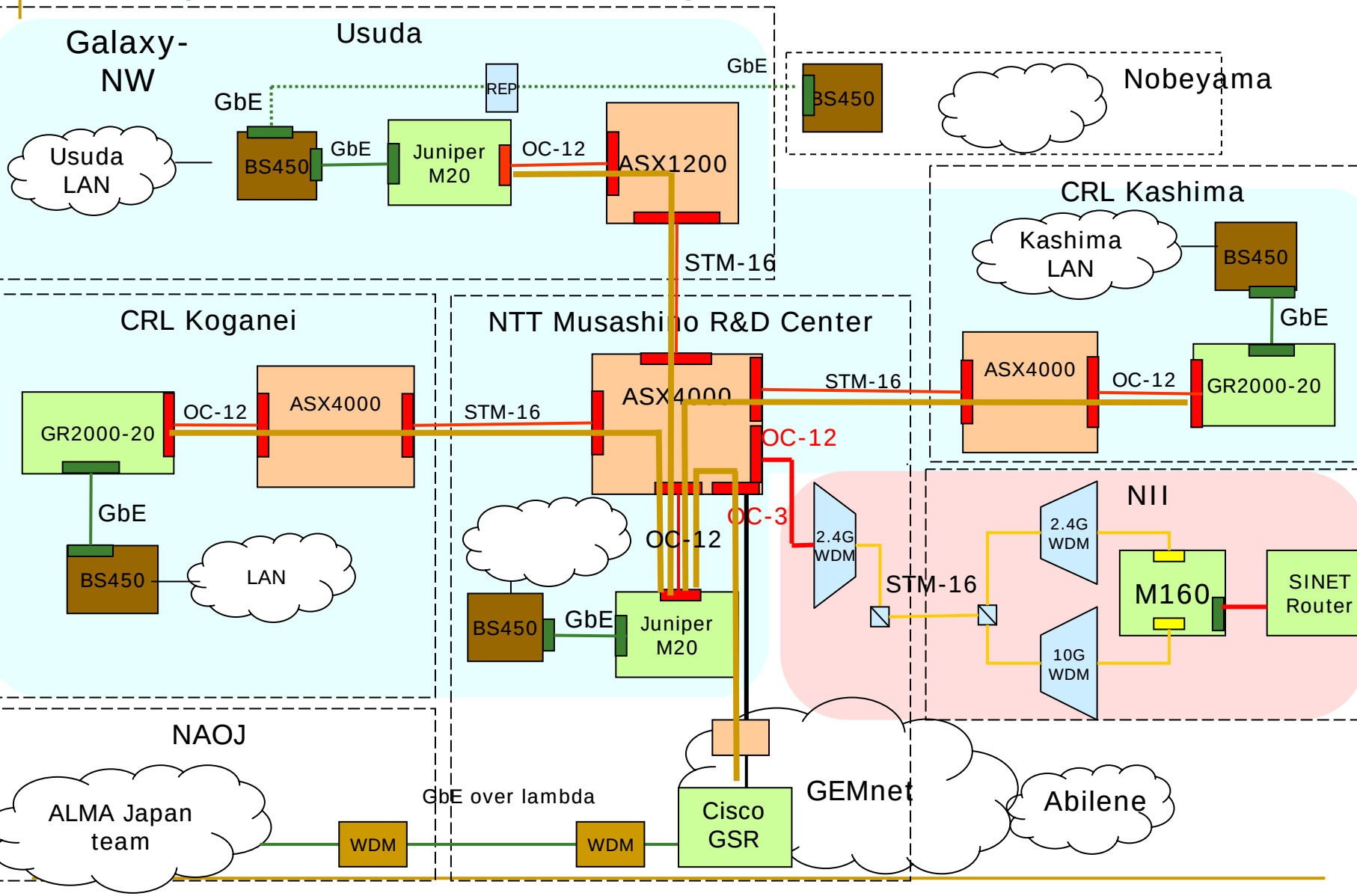
IP-transmitting PCs



IP-receiving PCs and ID1 serializer

sampler and ID1 parallelizer

Example of Network Configuration

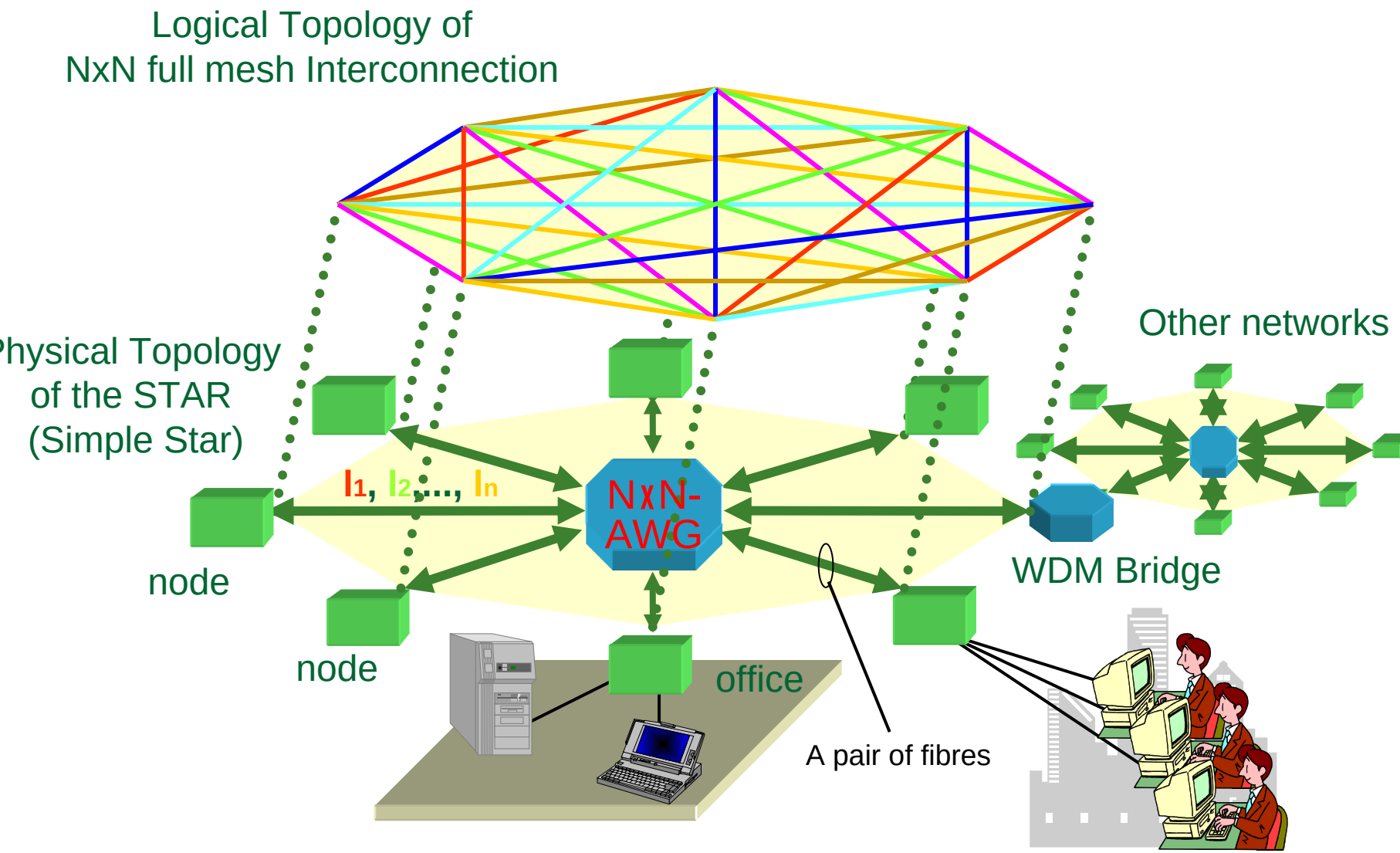


ATM Switch at NTT Musashino (ASX4000)

MPEG2 Video Conference System (Usuda)

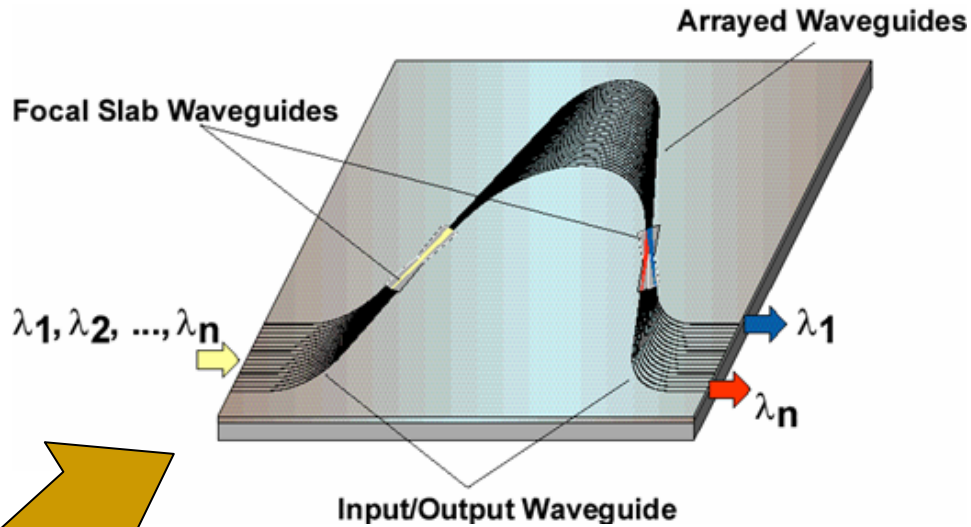
MPEG2 Video Conference System (Musashino)

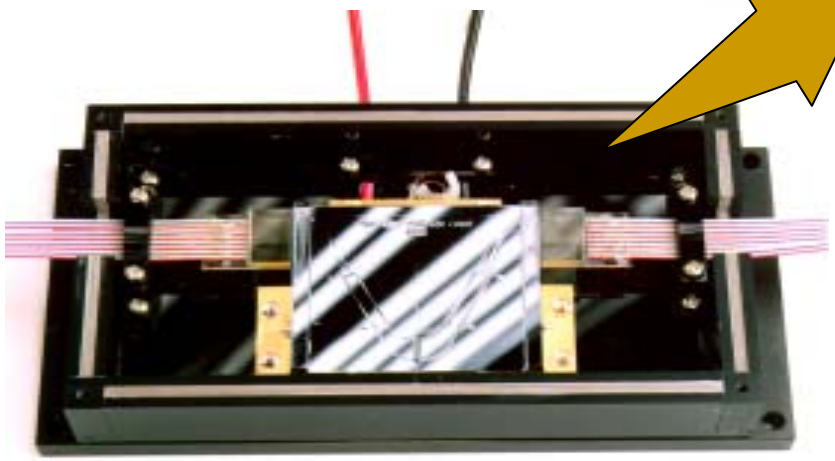
Network Upgrade: Full-mesh lambda network



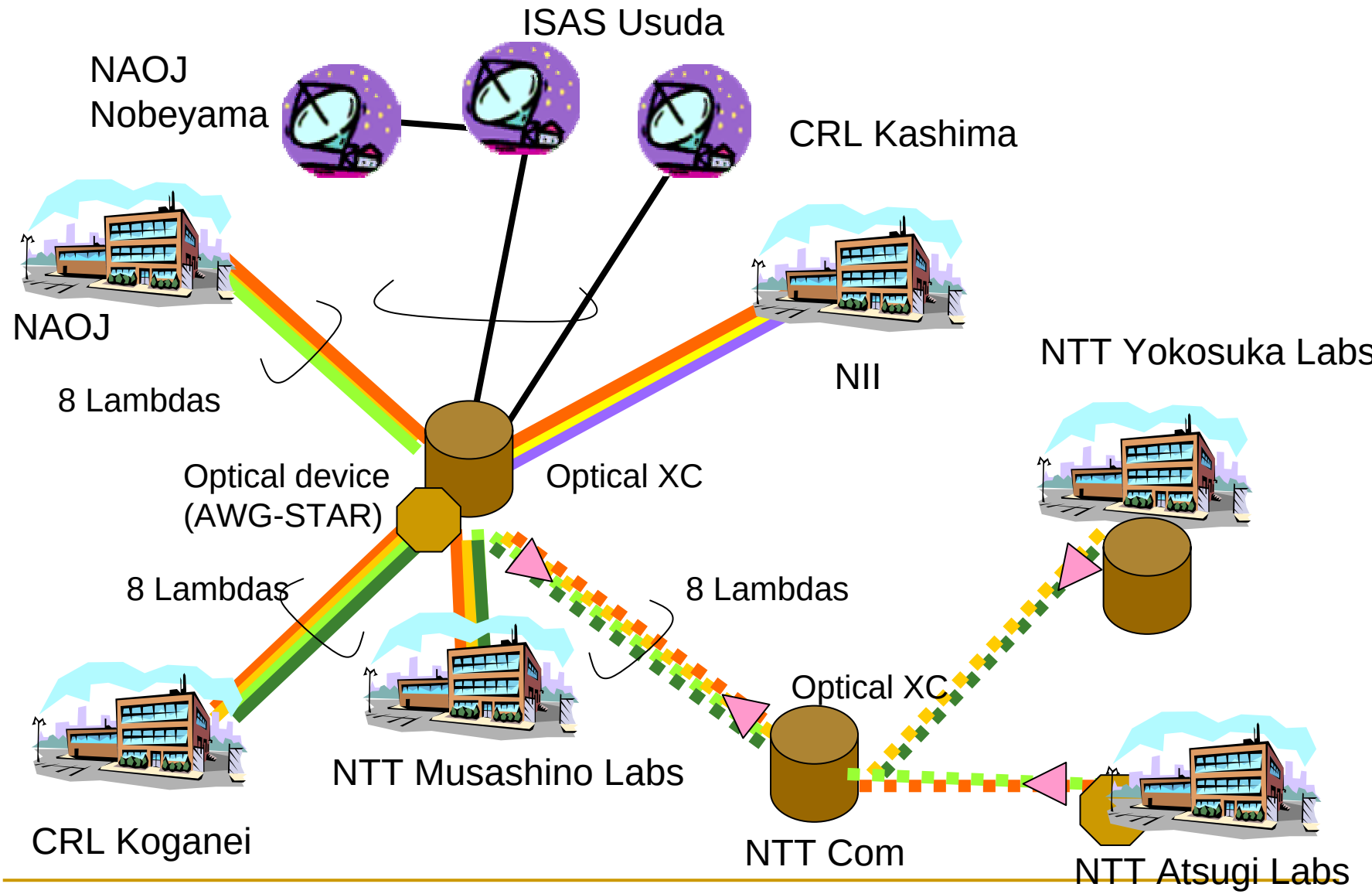
Arrayed Waveguide Grating developed by NTT

- WDM filter with silica-based PLC technology
- Multi-demultiplexing multiple WDM signals simultaneously

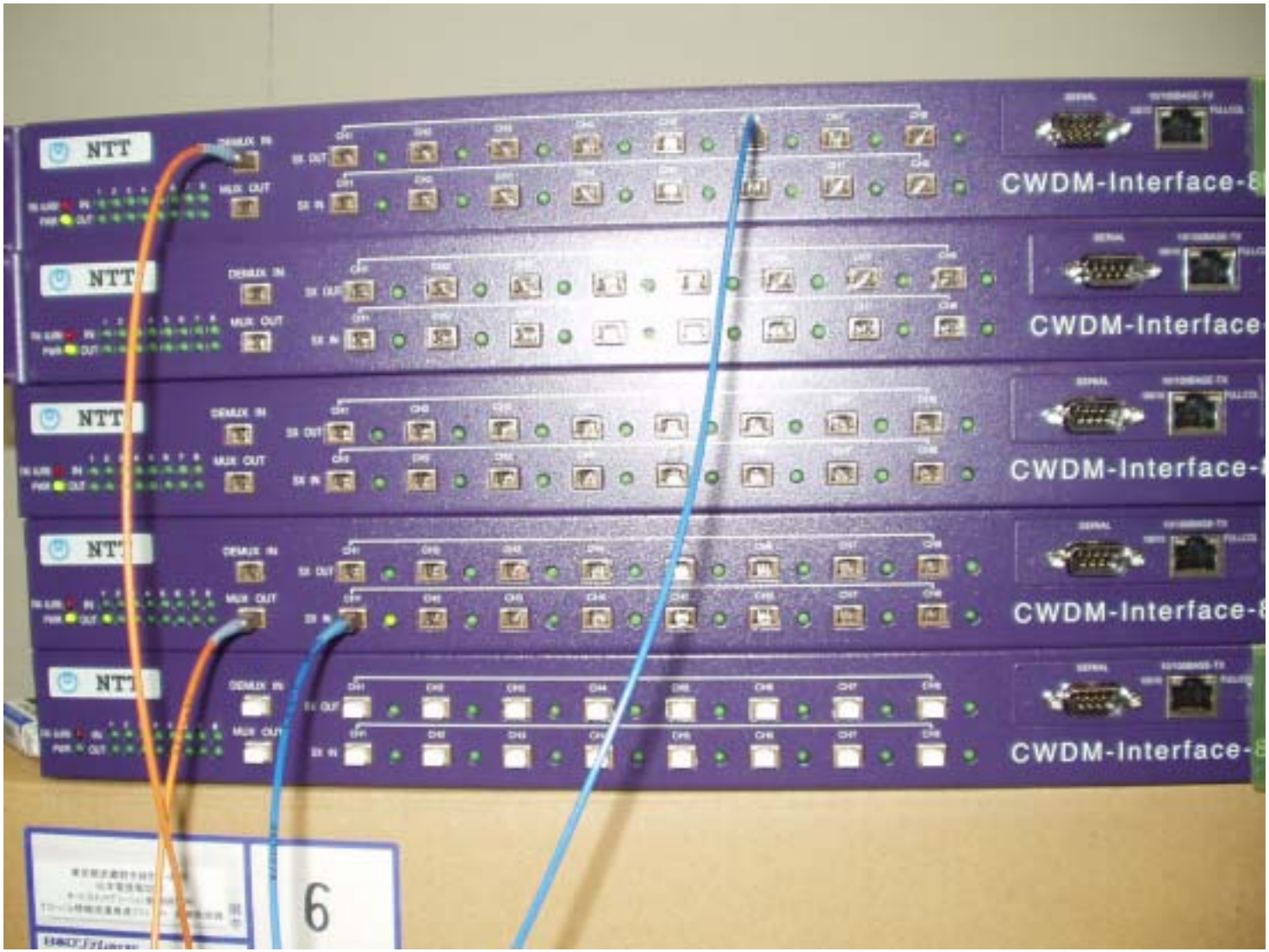




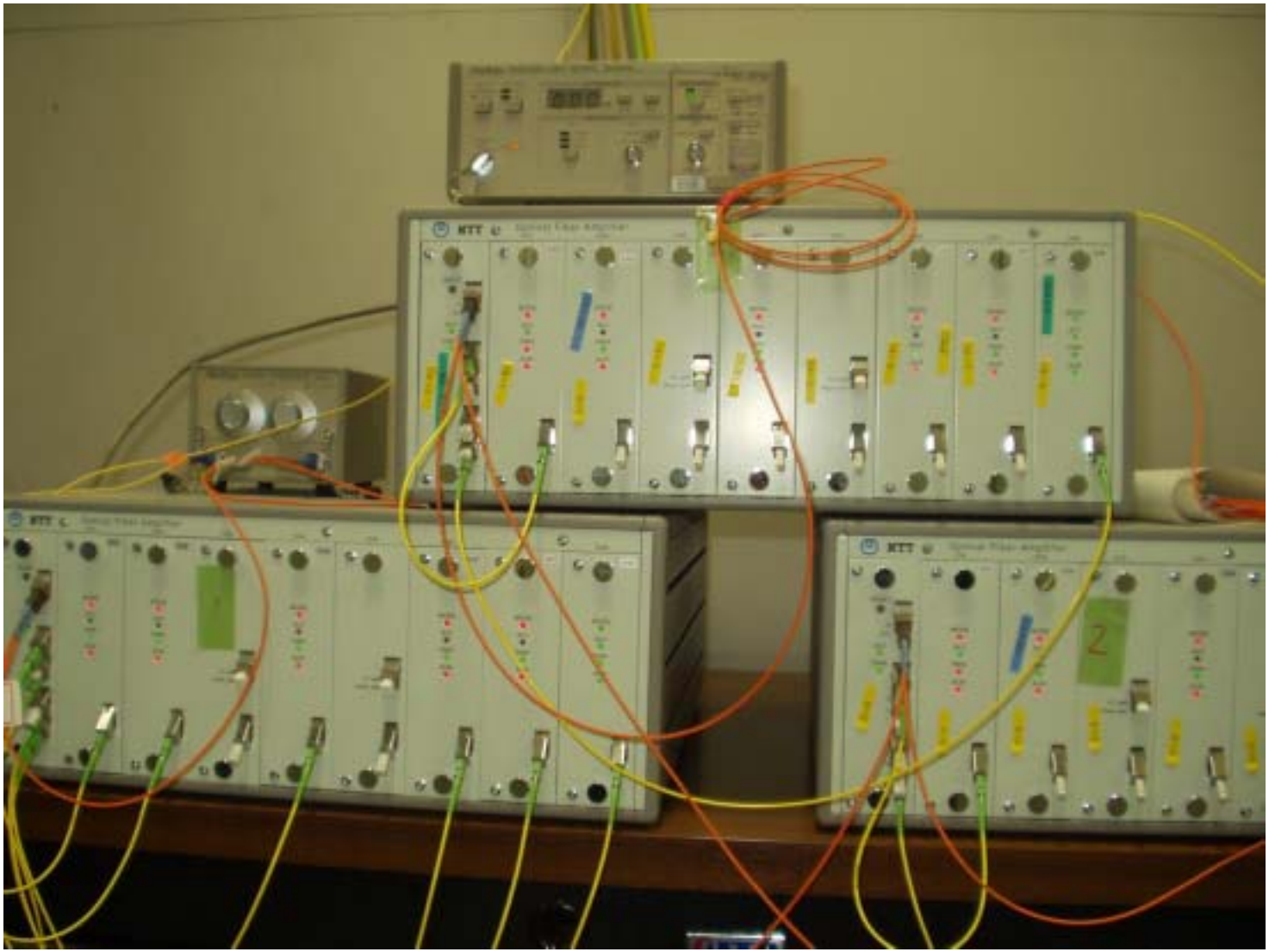
Network Upgrade with WDM Technologies



CWDM Multiplexers



Optical Amplifiers for CWDM signals



Experiment between Kashima and Westford

- Mar. 25, 2003 (evlbi4)
  - Westford (Mk5)-Kashima34m(K5), 2 hours, 56Mbps
  - Fringes were found on Mar. 27!

Courtesy of CRL

Remote Control of ALMA Test Instruments

Remote monitoring of ALMA test instruments with the cooperation of Internet2, AMPATH and REUNA

San Pedro de Atacama

NAOJ Base

NAOJ Mitaka Campus

Japan

NTT

Musashino R&D Center

Trans Pacific

GEMnet

US

Abilene

Trans Americas

AMPATH

Chile

REUNA

U. Chile

Partner R&E Networks

Future Plan

- I'll try to continue GALAXY project from NTT side by
  - Combining our effort with NTT's other R&D on broadband communications
  - Combining the GALAXY network infrastructure with NTT's research network (GEMnet)
  - Introducing the latest photonic network technologies to be used under the actual ultra-high-speed applications
  - Collaborating with other GALAXY members (CRL, NAOJ, ISAS and universities) and extending the connection to other antennas within Japan
  - Collaborating with e-VLBI community outside Japan
  - Collaborating with R&E networks/institutes including SINET (NII), Abilene (Internet2), Pacific Wave (UW), StarLight, AMPATH (FIU) and REUNA

Thank you very much!