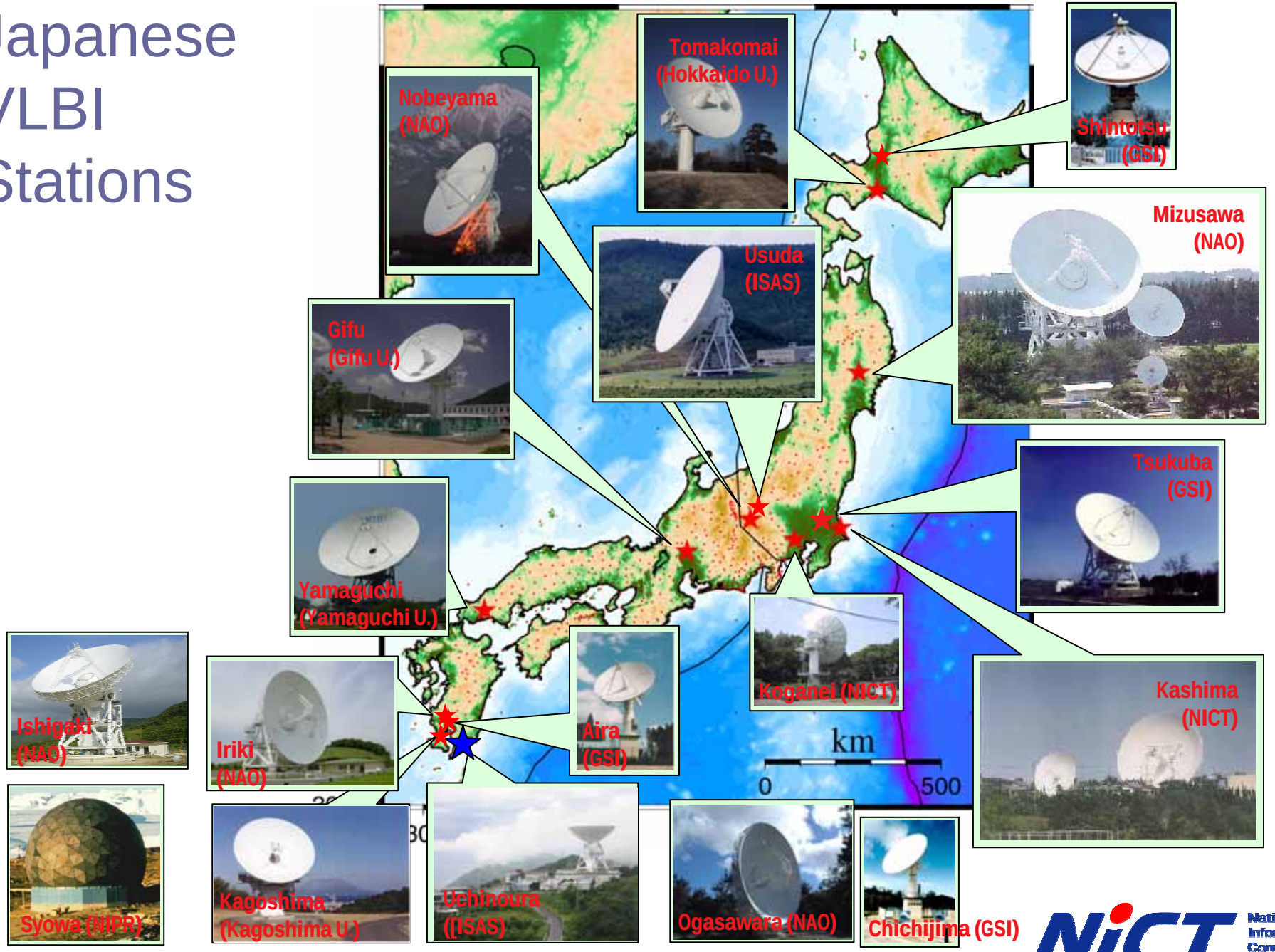
Review of Japanese e-VLBI work

Yasuhiro Koyama (Kashima Space Research Center, NICT)

National Institute of Information and Communications Technology

Japanese VLBI Stations



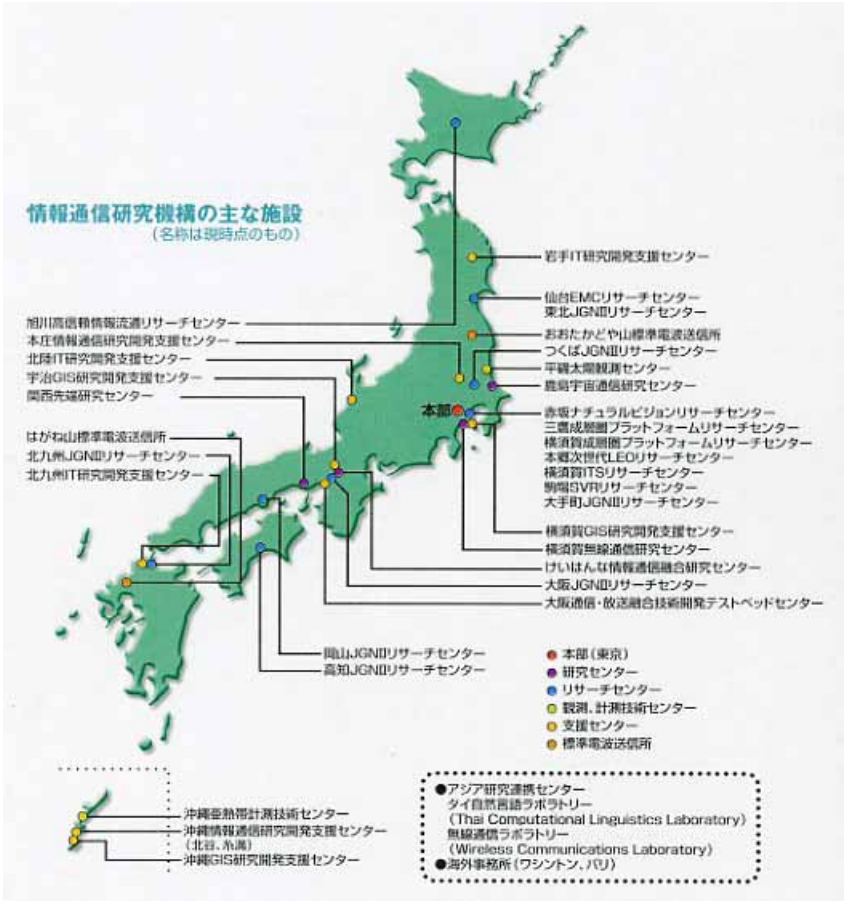
National Institute of Information and Communications Technology

Organizations

- National Institute of Information and Communications Technology (NICT)
  - Kashima Space Research Center (34m, 11m)
  - Koganei (11m)
- National Astronomical Observatory (NAO)
  - Nobeyama Radio Observatory (45m)
  - VERA (Mizusawa 20m+10m, Ogasawara 20m, Iriki 20m, Ishigaki, 20m)
- Japan Aerospace Exploration Agency (JAXA)
  - ISAS (Usuda 64m, Haruka=VSOP 8m, Uchinoura 34m : coming soon)
- Geographical Survey Institute (GSI)
  - Tsukuba (32m), Chichijima (10.3m), Aira (10.3m), Shintotsukawa (3.8m)
- National Institute of Polar Research (NIPR)
  - Syowa Station in Antarctica (11m)
- Universities
  - Gifu (11m+3m), Yamaguchi (32m), Hokkaido (11m), Kagoshima (6m)

NiCT National Institute of Information and Communications Technology

National Institute of Information and Communications Technology



- Established on April 1, 2004 by merging two organizations.
  - Communications Research Laboratory (CRL)
    - CRL was established after Radio Research Laboratory in 1988.
  - Telecommunications Advancement Organization (TAO)
- Incorporated Administrative Agency
  - Independent managements, not belonging the government.
  - Evaluation by the government every 5 years (current term : 2001-2005).

NiCT National Institute of Information and Communications Technology

Kashima Space Research Center

- Three research groups
  - Mobile Satellite Communications Group
  - Space Cybernetics Group
  - Radio Astronomy Applications Group
- 34m antenna
  - L*, S/X, 5GHz*, 22GHz, 32GHz, 43GHz

  * L-band and 5GHz receivers are barely used
- 11m antenna
  - S/X
- 26m antenna
  - S/X
  - Dismantled in March 2003

NiCT National Institute of Information and Communications Technology

Radio Astronomy Applications Group

From left

- Ryuichi Ichikawa
- Moritaka Kimura
- Hiroshi Takeuchi
- Shinobu Arimura
- Tetsuro Kondo
- Mamoru Sekido
- Hiromitsu Kuboki
- Eiji Kawai
- Yasuhiro Koyama

NiCT National Institute of Information and Communications Technology

VLBI R&D at Kashima

- IVS (International VLBI Service for Geodesy and Astrometry)
  - Technology Development Center, Data Center, Analysis Center, Correlator, Network Stations (KASHIM34 KASHIM11 KOGANEI)
- e-VLBI
  - PC-based data acquisition systems
  - Distributed software correlation processing
- Spacecraft orbit determination
  - ISAS missions (GEOTAIL, NOZOMI, HAYABUSA)
- High sensitivity VLBI
  - Giga-bit VLBI systems (GBR2000D, GICO, GICO2)
  - CARAVAL system (transportable 60cm dish)
- Standardization
  - VSI-H, VSI-S, VSI-E

VLBI Systems for e-VLBI


K3 Correlator (Center)
K3 Recorder (Right)

K4 Terminal

K4 Correlator


K5 Data Acquisition Terminal

K3 System

1983~
Longitudinal Recorder
Open Reel Tapes
Hardware Correlator

K4 (KSP) System

1990~
Rotary Head Recorder
Cassette Tapes
Hardware Correlator
e-VLBI with ATM

K5 System

2000~
PC based system
Hard Disks
Software Correlator
e-VLBI with IP

NiCT National Institute of Information and Communications Technology

K5 Family : Concept

ADS1000
(1024Msample/sec 1ch 1bit or 2bits)

ADS2000
(64Msample/ch·sec, 16ch, 1bit or 2bits)

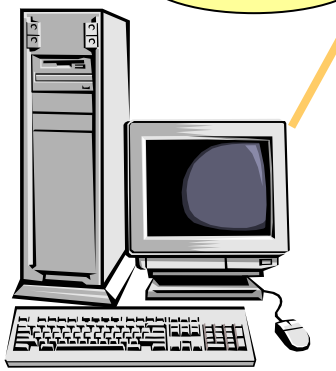
PC-VSI Board
(Supports VSI-H specifications)

VSI

VSI

Correlator
other DAS

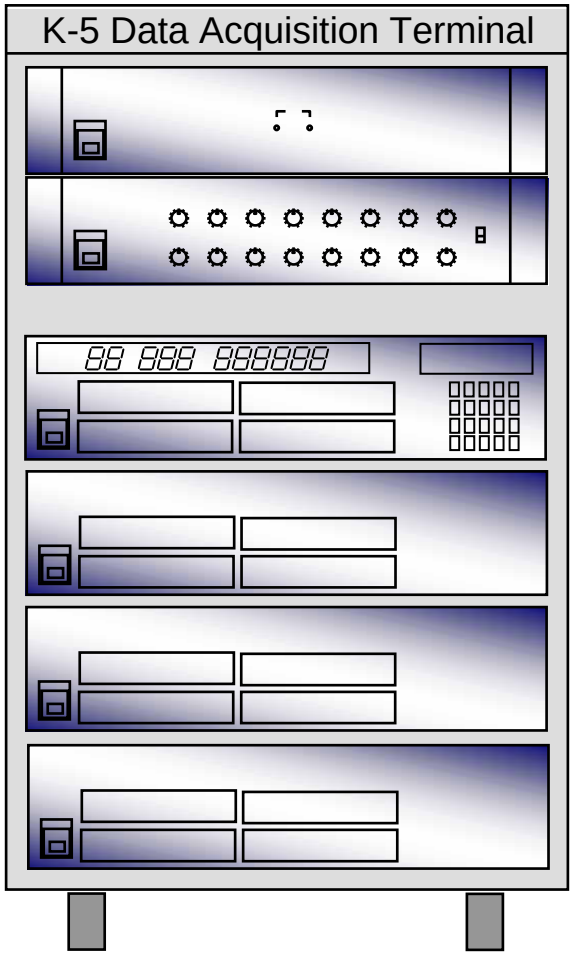
Internet



IP-VLBI Board
(~16Msample/ch·sec, ~4ch, ~8bits)

PC : Data Acquisition
Correlation

NiCT National Institute of Information and Communications Technology



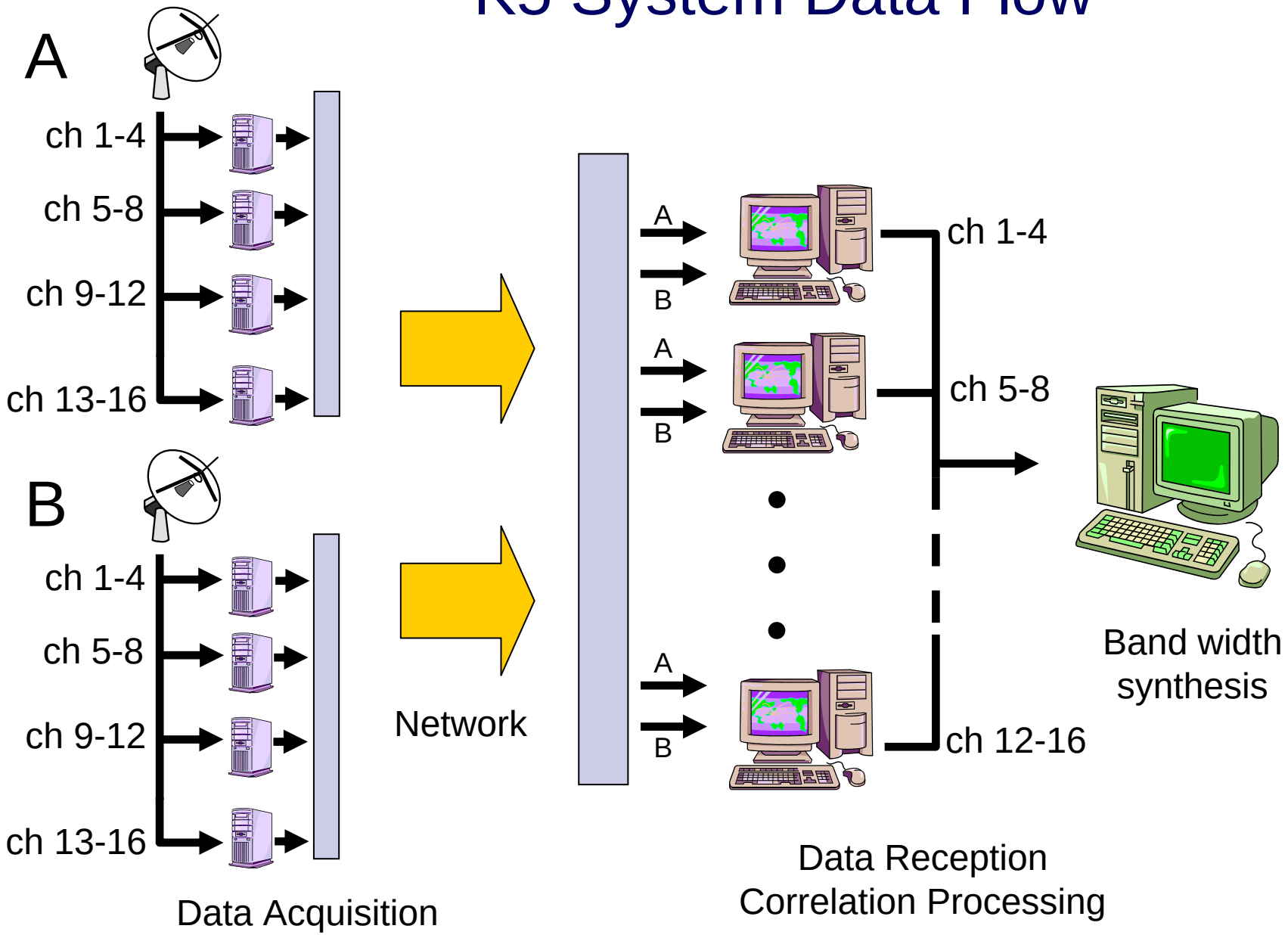
7625A (Reference signal distributor)

7626 (16ch video amps)

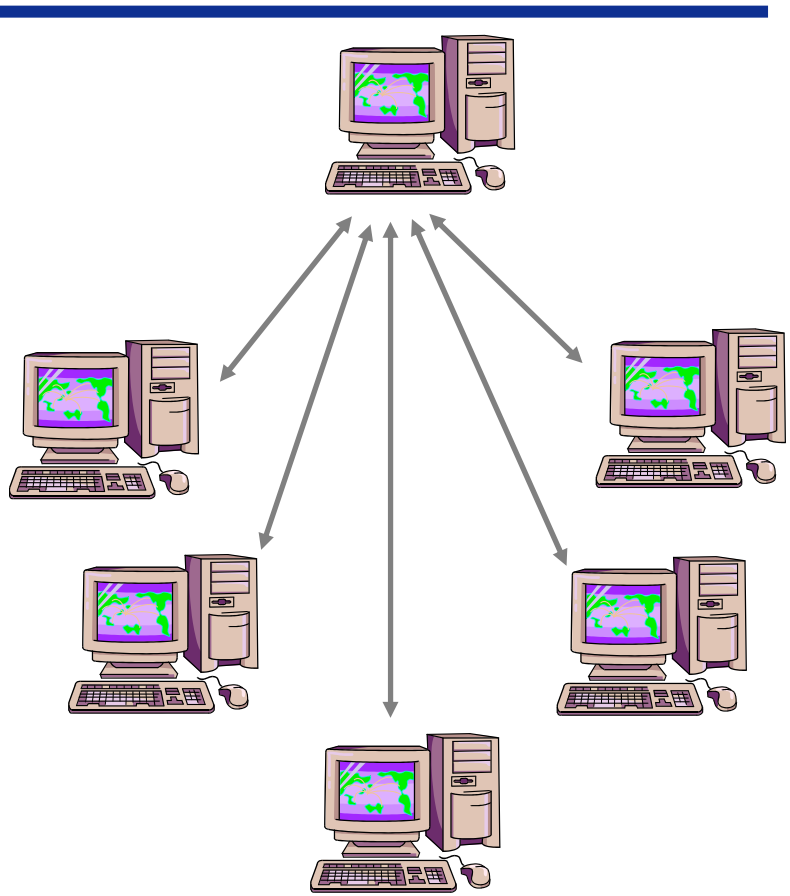
Rack mount PC
with an IP-VLBI
board (9260)
and 4 removable
HDD x 4

National Institute of Information and Communications Technology

K5 System Data Flow



CPU array for Software Correlation



Correlation Master Table/Database

National Institute of Information and Communications Technology

e-VLBI : History

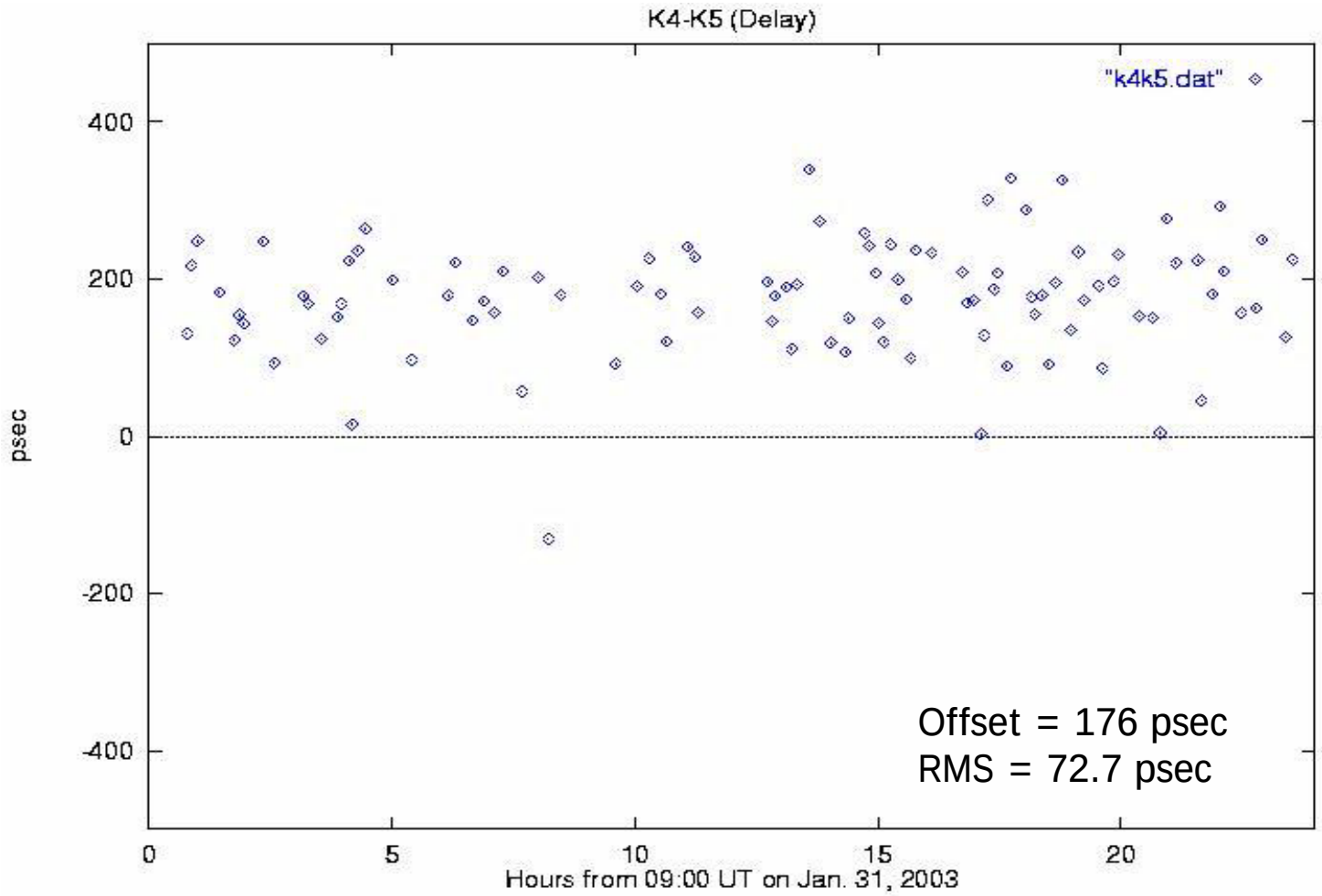
- ATM based real-time VLBI
  - 1996.4.11 First real-time fringe at 64Mbps (Kashima-Koganei baseline)
  - 1996.5.1 First real-time fringe at 256Mbps (Kashima-Koganei baseline)
  - 1997.6.4 Started daily 6 baselines real-time VLBI sessions at 256Mbps
  - 2001.6.23 First real-time fringe at 1024Mbps (Kashima-Usuda baseline)
  - 2001.12.12 First real-time fringe at 2048Mbps (Kashima 26m-34m)
- IP based e-VLBI (ftp-VLBI)
  - 2000.9.12 First K5-K5 fringe at 4Mbps/ch. (Kashima 26m-34m)
  - 2002.10.8 First K5-Mark5 fringe at 64Mbps (Kashima-Westford)
  - 2002.10.16 First K5/VSI-PCEVN fringe at 1Gbps (Kashima-Metsähovi)
  - 2003.1.31 First 24hours geodetic VLBI with K5 (Kashima-Koganei)
  - 2003.6.27 Successful estimation of UT1-UTC within 21 hours after a VLBI session (Kashima-Westford)

Domestic VLBI Experiments with K5 System

- Jan. 30-31, 2003 (U03031)
  - Single baseline experiment : Kashima (11m) and Koganei (11m)
  - 56Mbps (2MHz, 14ch.), 24 hours
  - Compared results with K4 and GBR systems

- July 16-17, 2003 (JADE0306)
  - 5 stations, 10 baselines : Kashima (11m), Tsukuba (32m), Tomakomai (11m), Gifu (11m), Yamaguchi (32m)
  - The first geodetiv VLBI for Yamaguchi (32m) station : X-band only
  - 128Mbps (4MHz, 16ch.), 24 hours
  - up to ~1.4TBytes

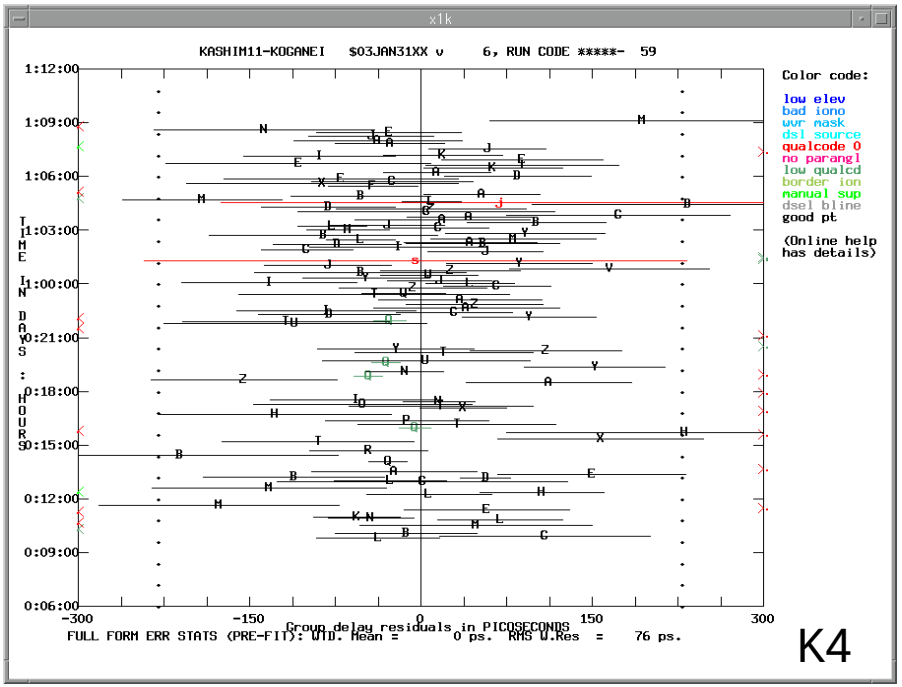
Comparison in Time Delay (U03031)

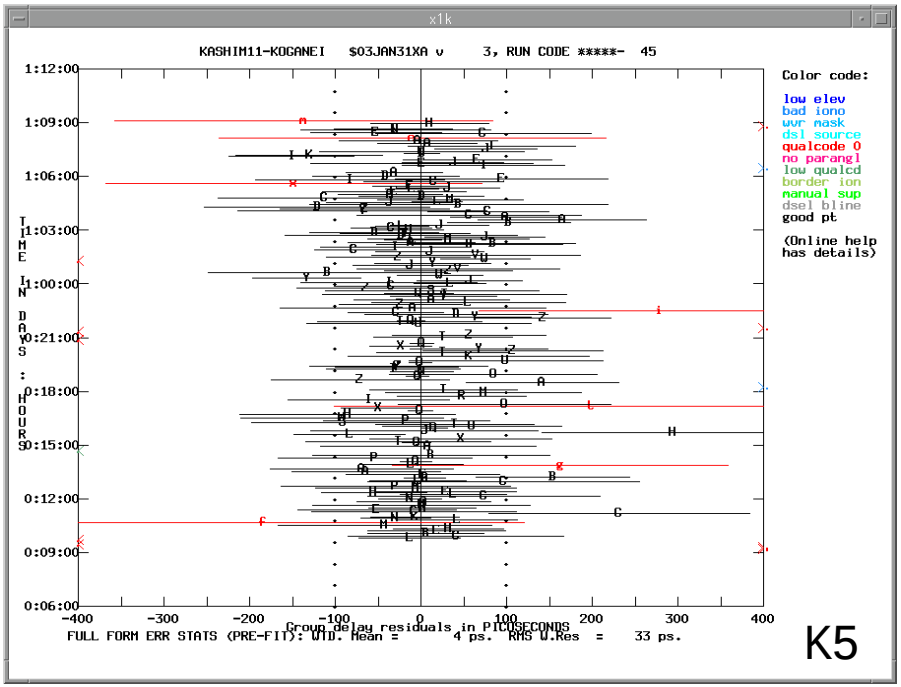


National Institute of Information and Communications Technology

Comparison of Results (U03031)

Delay Residual





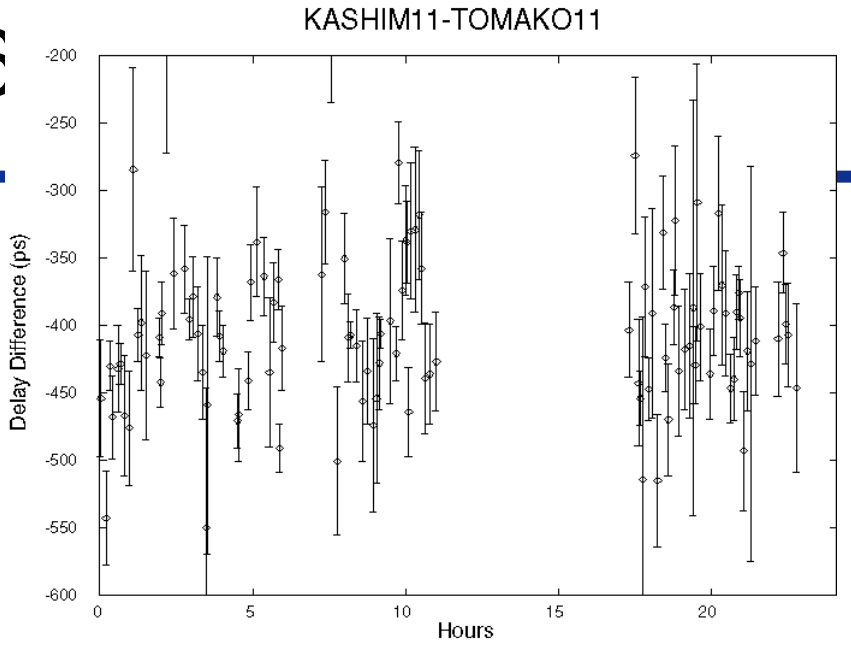
Data Analysis Results

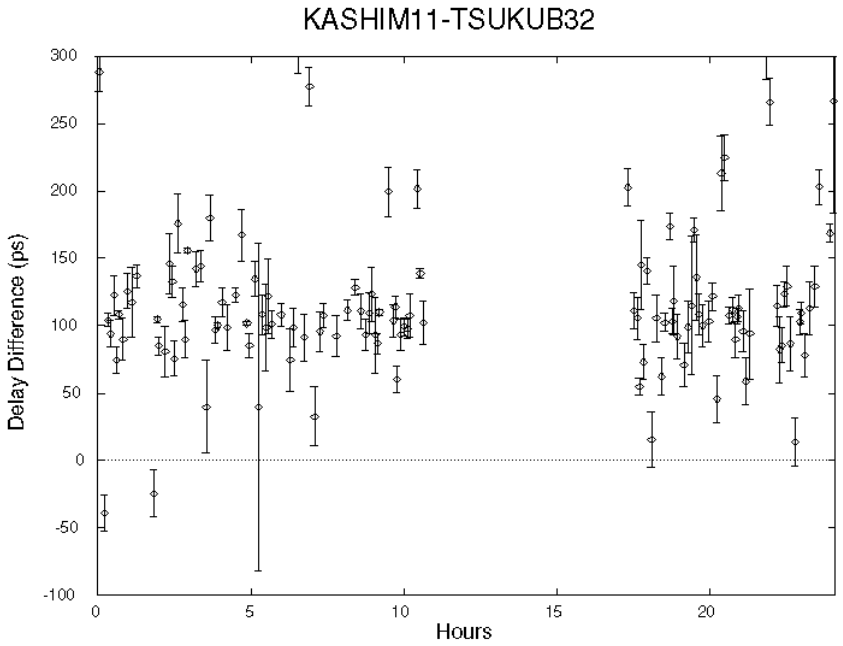
	Baseline Length	Delay RMS	Delay Rate RMS
K4	109099657.0±6.7mm	76 psec	136 fsec/sec
K5	109099641.2±3.2mm	33 psec	92 fsec/sec

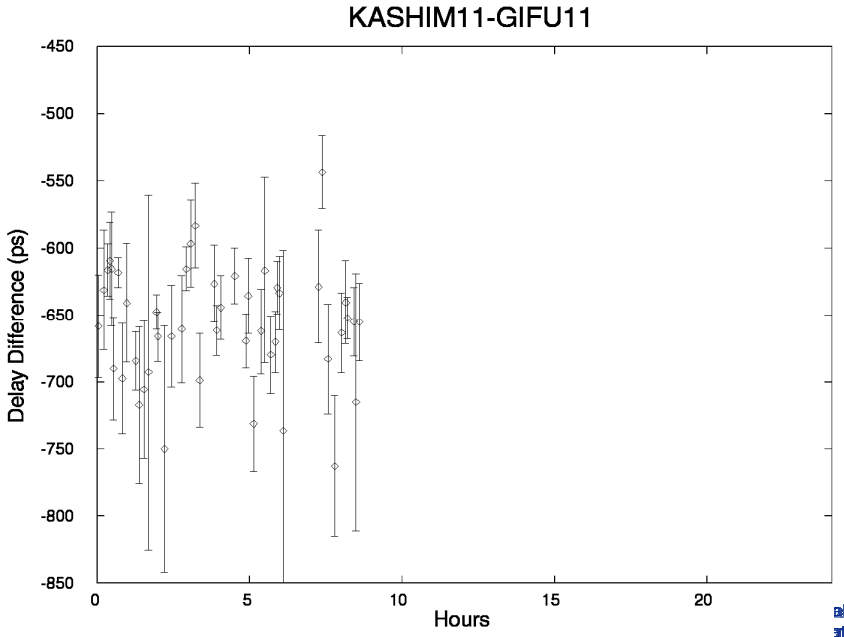
National Institute of Information and Communications Technology

Time Delay (JADE0306

	Average	RMS
KASHIMA-TSUKUBA	113.3 ps	50.9 ps
KASHIMA-TSUKUBA	-658.0 ps	44.3 ps
KASHIMA-TOMAKOMAI	-404.1 ps	61.0 ps







Comparisons of Results (JADE0306)

Baseline	System	No. of valid data	Baseline Length (mm)	RMS Residual Delay (psec)	RMS Residual Rate (fsec/sec)
Tsukuba-Kashima	K4	176	53811894.9 ± 2.1	53	158
	K5	130	53811891.6 ± 3.1	81	121
Tsukuba-Gifu	K4	184	311067474.0 ± 2.9	98	189
	K5	55	311067483.3 ± 4.0	58	136
Tsukuba-Tomakomai	K4	124	740526116.3 ± 4.4	103	165
	K5	169	740526119.4 ± 5.1	103	146
Kashima-Gifu	K4	174	358799168.6 ± 2.8	72	191
	K5	48	358799174.7 ± 4.5	92	144
Kashima-Tomakomai	K4	171	749810979.9 ± 4.4	115	125
	K5	108	749810985.5 ± 5.5	106	143
Gifu -Tomakomai	K4	154	902668931.2 ± 4.8	135	125
	K5	49	902668930.6 ± 6.1	116	138

Westford-Kashima Experiments for Rapid UT1-UTC

- Mar. 25, 2003 (evlbi4)
  - Westford (Mk5)-Kashima34m(K5), 2 hours, 56Mbps
  - Fringes were found on Mar. 27!
- Jun. 27, 2003 (evlbi6)
  - Westford (Mk5)-Kashima34m(K5), 2 hours, 56Mbps
  - UT1-UTC estimation 21 hours after the observations!

NiCT National Institute of Information and Communications Technology

	Source Name	Duration (sec)	File Size (Mark5)	File Size (K5)
1	4C39.25	90	1,620 Mbytes	180 Mbytes x 4
2	1736+455	200	3,600	400 x 4
3	1357+769	90	1,620	180 x 4
4	0059+581	250	4,500	500 x 4
5	2234+282	310	5,580	620 x 4
6	1300+580	140	2,520	280 x 4
7	0955+476	90	1,620	180 x 4
8	2113+293	300	5,400	600 x 4
9	1739+522	500	9,000	1,000 x 4
10	1357+769	90	1,620	180 x 4
11	0059+581	270	4,860	540 x 4
12	2234+282	510	9,180	1,020 x 4
13	1044+719	784	1,4112	1,568 x 4
14	1128+385	180	3,240	360 x 4
15	1300+580	130	2,340	260 x 4
16	0955+476	90	1,620	180 x 4
17	2113+293	390	7,020	780 x 4
18	1739+522	530	9,540	1,060 x 4
19	1357+769	90	1,620	180 x 4
Total		5,034	90,612 Mbytes	40,272 Mbytes

e-VLBI4 data processing

File Transfer ~ 20 hours

Delay = 234 msec
Buffer Size = 64 kbytes
Speed
= 2.2 Mbps / Connection
= 11 Mbps (5 connections)

Correlation ~ 20 hours with 4 PCs

Bandwidth Synthesis ~ 10 min.

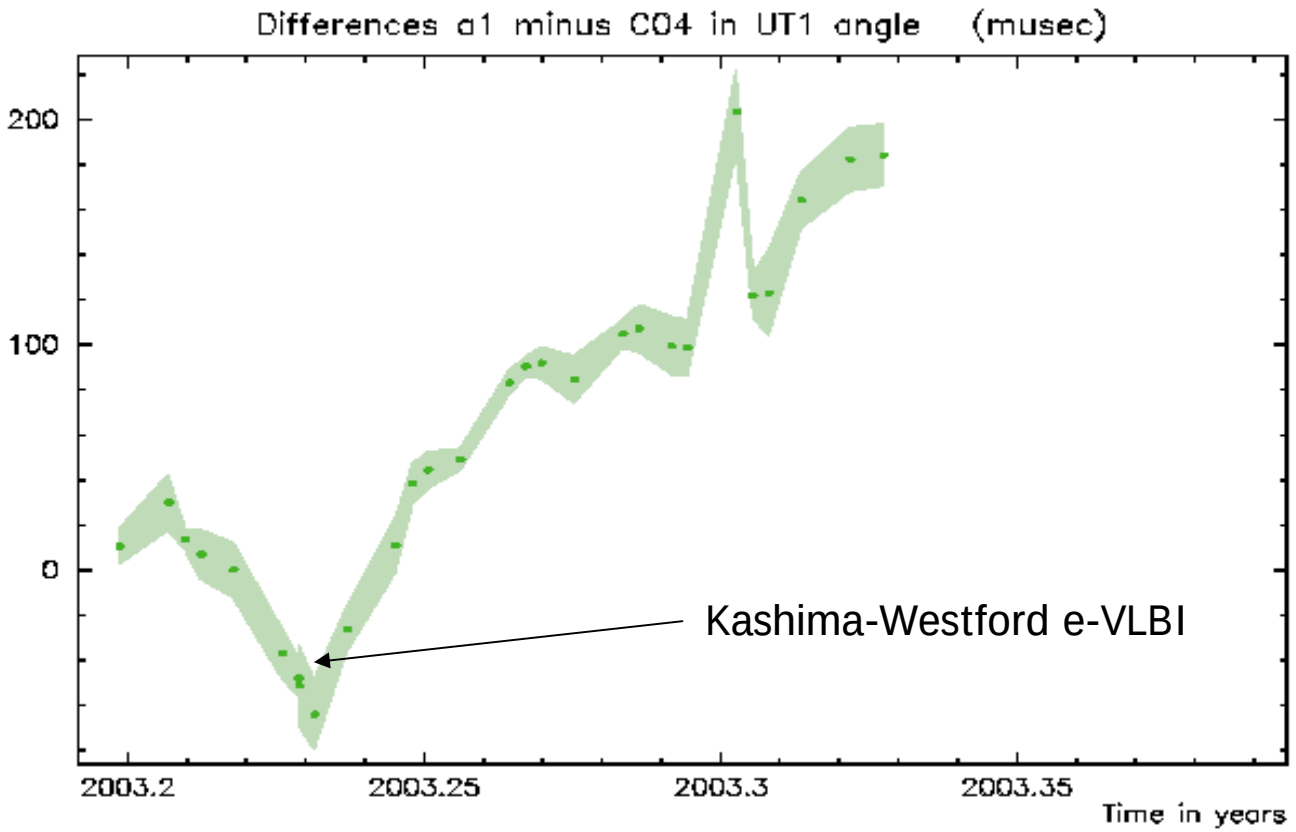
Data Analysis ~ 1 hour

UT1-TAI
= -32338.7280 +/- 23.90
(micro sec)

NiCT National Institute of Information and Communications Technology

Consistency of UT1-UTC Results

UT1-UTC estimation compared with NEOS Intensive VLBI sessions



* Data analysis done by Dr. Leonid Petrov at Goddard Space Flight Center, NASA

National Institute of Information and Communications Technology

Time Sequence of Data Transfer and Processing

e-VLBI6

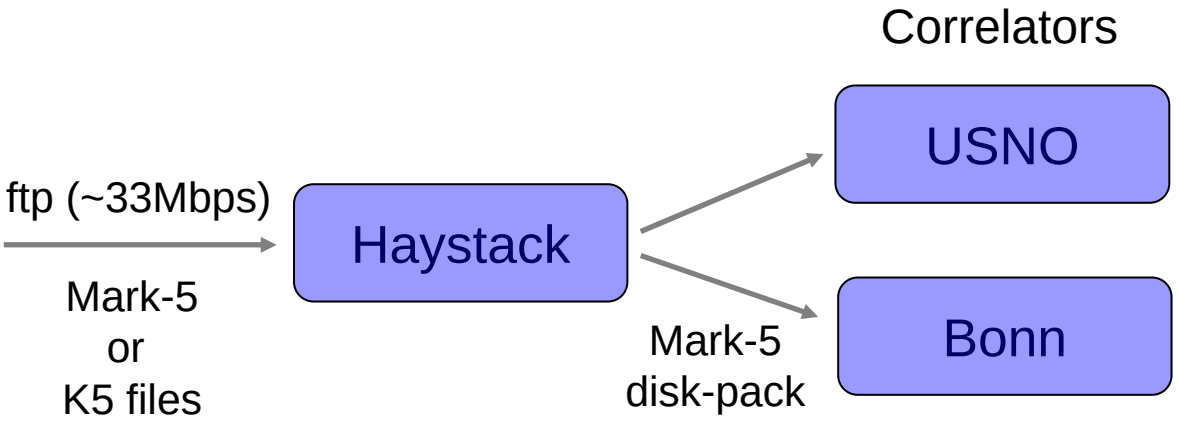
- 22:00 (JST) Observations Start
- 00:00 Observations End
- ~04:20 File extraction and transmission
  - From Kashima to Westford : 107Mbps 41.54GByte in 51m 35s
  - From Westford to Kashima : 44.6Mbps 41.54GByte in 2hr 04m 02s
- ~08:10 File Conversion (Mark5 to K5)
- ~20:30 Software Correlation
- ~21:20 Bandwidth Synthesis Processing, Database Generation, Data Analysis

* Correlation at Haystack Observatory (Mark4 Correlator) finished at 14:19 JST

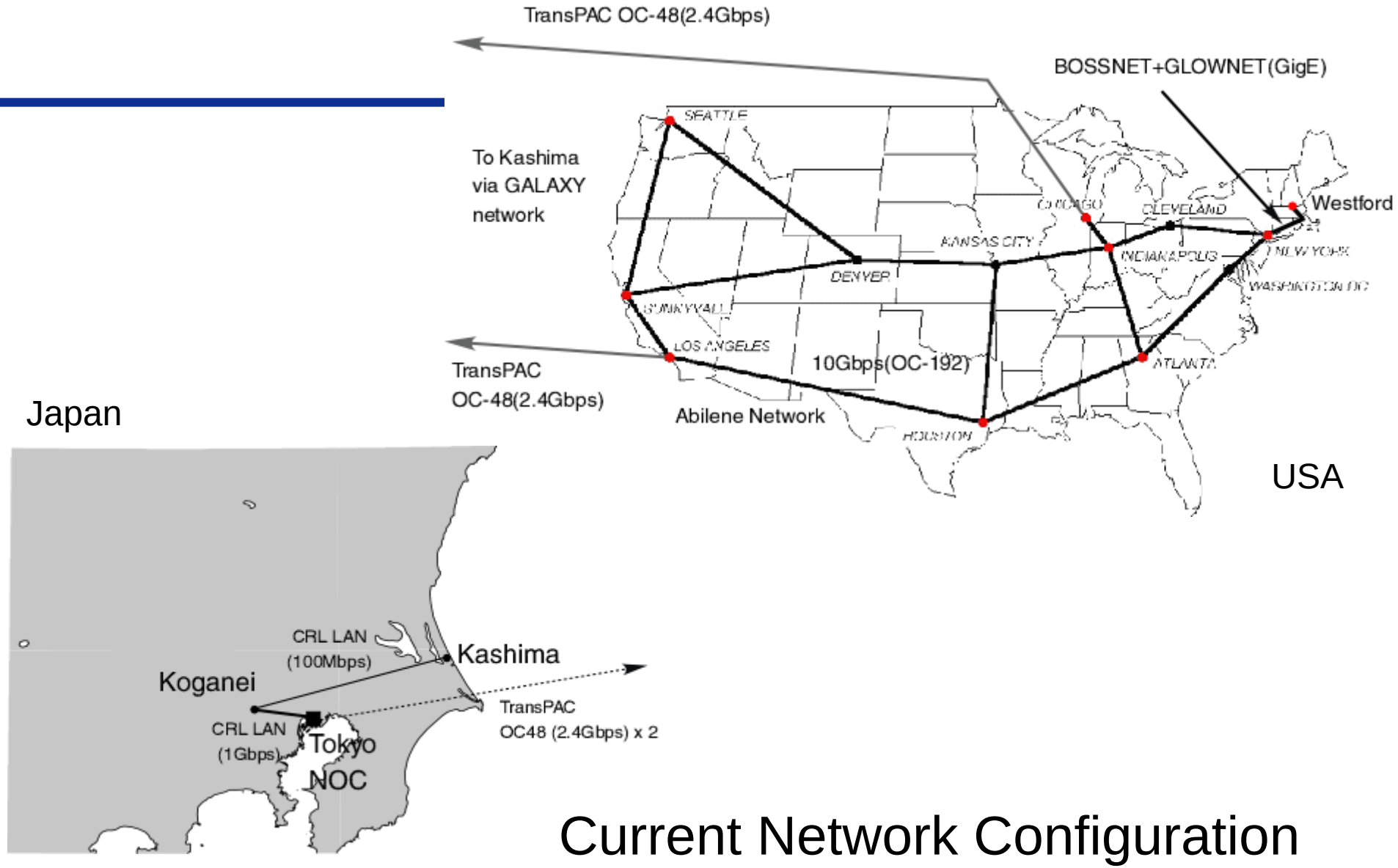
Use of K5 System in IVS Sessions

- Following 4 IVS sessions at Kashima were recorded with VLBA and K5 systems in parallel
  - IVS-CRF22 October 28-29, 2003
  - IVS-CRF23 November 4-5, 2003
  - IVS-T2023 November 18-19, 2003
  - IVS-T2024 December 2-3, 2003

K5 files → Mark-5 files
(except for T2024)



National Institute of Information and Communications Technology

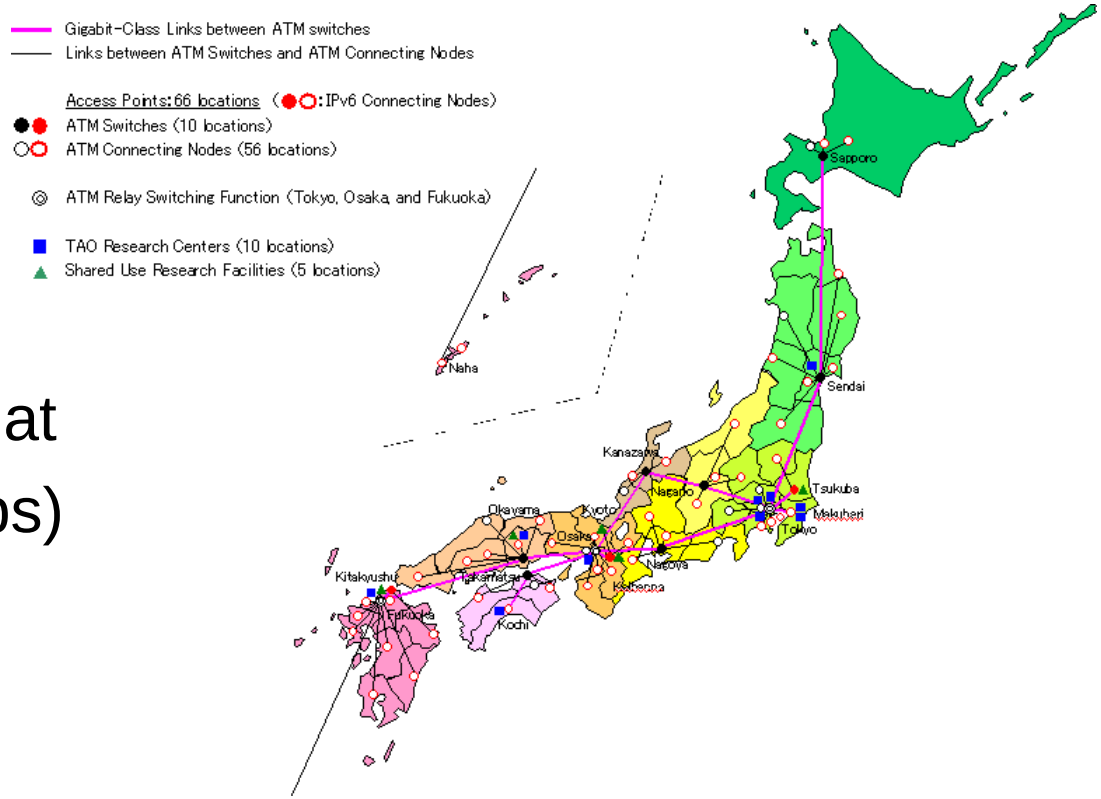


Current Network Configuration

National Institute of Information and Communications Technology

JGNII (Japan Gigabit Network II)

- Following project of JGN by TAO
- Operated by NICT
- up to 10 Gbps
- opened for public use in April 2004
- Connected to Internet2 via TransPAC (622Mbps at present, soon to be 1Gbps)



National Institute of Information and Communications Technology

Future Plan

- Improve data transfer speed.
  - Network speed upgrade at Kashima : 100Mbps => 10Gbps
  - Further tuning.
  - Replace slow network instruments.
  - Examine high performance protocols (HS-TCP, FAST, etc.).
- Develop Software Correlator with CPU Array System.
- Real-time data transfer and real-time correlation with IP.
- Regular use of K5 system in IVS sessions (on going).
  - Kashima, Syowa (Antarctica), and Tsukuba.
- Digital BBC Program to cover more observation modes.
- VSI-E (Standard Protocol for VLBI) realization.
  - Eliminate necessity of file format conversion.

- NICT will organize the 3rd e-VLBI workshop at Makuhari, Japan (October 6-7, 2004).

- Please participate!!

NiCT National Institute of Information and Communications Technology