



JPL

Trans-Pacific Astronomy Experiment Project Status

Japan-U.S. Science, Technology and Space Applications
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Remote Astronomy over Trans-Pacific ATM Satellites

Trans-Pacific Astronomy Experiment

- Phase 2 of the *Trans-Pacific High Data Rate Satcom Experiments* following the Trans-Pacific High Definition Video Experiment
- Satellite Communications in the Global Information Infrastructure
 - Emerging global information infrastructure involving broadband satellites and terrestrial networks
 - Access to information by anyone, anywhere, at any time
 - Collaboration of government, industry, and academic organizations
- Demonstrate the use of broadband satellite links in a global information infrastructure with emphasis on astronomical observations, collaborative discussions and distance learning

(cont.)

Remote Astronomy over Trans-Pacific ATM Satellites

- **Interactive control of Mt. Wilson Observatory's 24" telescope**
- **Distribution of Mt. Wilson Images through the use of distributed file access technology – people, organizations, and equipment are becoming more distributed in nature**
 - **Replication sites in Japan and the U.S.**
 - **Images from telescopes are stored in a distributed file system**
 - **Permits post-processing of images by other participants**
 - **Storage of Hubble Space Telescope archival images**
- **Environment for collaborative discussions and learning**
 - **A form of academic exchange between Japan and U.S. students**

(cont.)

Remote Astronomy over Trans-Pacific ATM Satellites

- **Internet Protocol (IP)-centric applications**
 - **IP-based applications are readily available to the general public**
 - **Involvement of schools and network researchers**
 - **Migration of research results to user applications**
- **An opportunity to study issues of scale and interoperability**
 - **IPv4 over ATM**
 - **IP Multicast (voice, video, and application data)**
 - **Distributed file access**
- **Application to other projects**
 - **e.g., NASA Solar System Internet/Mars Infrastructure effort**

Remote Astronomy over Trans-Pacific ATM Satellites

Issues to be examined:

- Effects of long propagation delay on information transfer and the use of storage as a part of the network infrastructure
- Obtain data for comparison between satcom and undersea links
- Introduction of distributed systems and multicast technologies as a part of the ultra wide area network infrastructure
 - Local preprocessing important on the interplanetary scale
 - Determine value of data before returning to maximize value
- Obtain performance data and compare with software-based models for solar system internet applications
- Possible foundation for integrating intelligent sensors and systems technology for space exploration

Remote Astronomy over Trans-Pacific ATM Satellites

Participation:

Asia Pacific Advanced Network (APAN)
BCNet
Comsat
Communications Research Laboratory
George Washington University
Intelsat
Japan Ministry of Posts and Telecommunications
Kokusai Denshin Denwa Co., Ltd.
Metronet
Misato Observatory
National Library of Medicine/National Institute of Health
Mt. Wilson Institute, in association with
 Crossroads (CA), T. Jefferson (VA) High Schools
 Soka High School (Japan)
NASA GSFC, JPL, NREN
Nippon Telegraph and Telephone
Sapporo University
Teleglobe
University of Maryland

Remote Astronomy over Trans-Pacific ATM Satellites

Potential Applications:

- Global Network of Astronomical Telescopes
- Global Oscillation Network Group
- University of North Carolina, Tennessee State University
- Astronomy community and the general public
- Satellite communications community
- Network and distributed systems protocol researchers
- NASA Science and Engineering Information Infrastructure
- NASA Collaborative Engineering Environment
- FAA FICS-21 (FAA Integrated Communications System for the 21th century)
- NASA Solar System Internet/Mars Infrastructure

Remote Astronomy over Trans-Pacific ATM Satellites

Interactive Observations

- Automated 24" telescope connected to a local telescope server
- Use of dedicated software for control and image capture
- Observations during day-time hours from Japan
- Use of distributed file access to propagate the images over satcom link

Remote Astronomy over Trans-Pacific ATM Satellites

IP-based Multicast

- Collaborative discussions during demonstrations
- Advantages: logical naming and efficient use of bandwidth for large, dynamic groups
- Virtual network - Casner: Multicast Backbone (MBone)
- Possible linkage with terrestrial MBone infrastructure
- Lecture mode vs. interactive mode over satcom links
- Layered encoding application

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Distributed File Access

- Effective means of sharing data
- Permits users to collaborate
- Access and location transparency
- Small local disk and shared file name space
- Server replication
- Facilitate transfers over satcom links
- Andrew File System (AFS)

Remote Astronomy over Trans-Pacific ATM Satellites

Virtual InterNetwork Testbed (VINT)

- Based on NS originally developed at LBNL
- NS - a discrete event simulator targeted at networking research. It provides substantial support for simulation of TCP, routing, and multicast protocols
- NAM - Network Animator
- Empirical error model provides simulation results for comparison
- Facilitates academic participation
- Helps examine the issues of scale and heterogeneity in the evolving global information infrastructure
- High bandwidth satellite links with terrestrial connections

Remote Astronomy over Trans-Pacific ATM Satellites

Status

- NASA Research and Education Network:
 - JPL-to-NASA ARC and GSFC established
 - PVC assigned: (0,55), (0,56)
 - NTTCP ATM level verification between JPL and GSFC
- Mt. Wilson Telescope
 - Via PacBell Internet
 - Internet version of software on 14" test telescope
 - Migration to 24" telescope
- Laboratory testbed at JPL
 - Mbone applications and measurement tools (mtrace)
 - AFS server and clients
 - Trans-Pacific Experiment cell created
 - Cell name: TPae.jpl.nasa.gov
 - Server name: afstpa01.jpl.nasa.gov
 - IP address: 137.79.116.64

Remote Astronomy over Trans-Pacific ATM Satellites
Network Test Plan

Status (cont.)

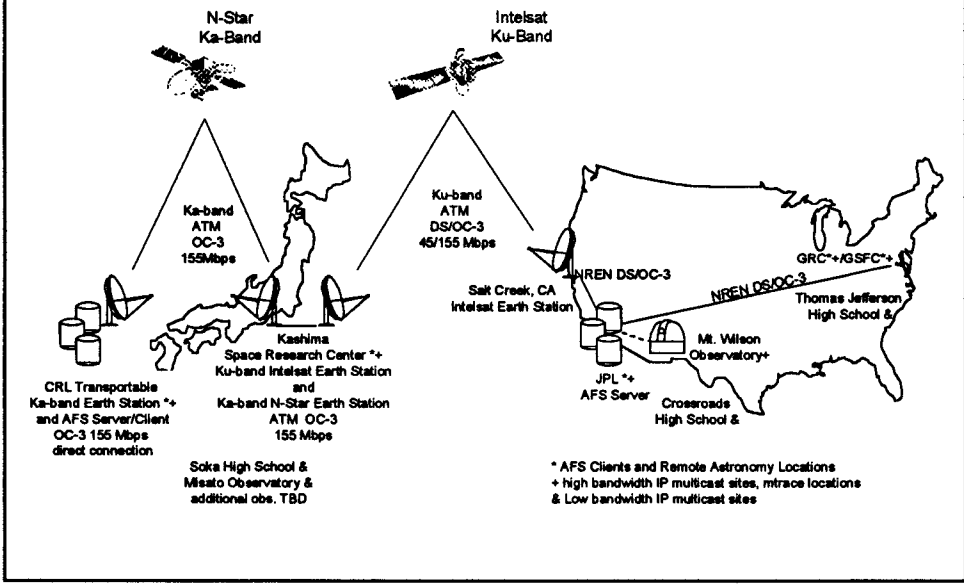
- Laboratory testbed at JPL (cont.)
 - PC-based Mbone application clients and AFS clients (presently requires protocol converter -- workstation)
 - Windows 98 needs light client (beta) or protocol converter
 - Testbed has two virtual subnets
 - Mbone tunnel
 - Satellite delay simulator
 - Andrew Benchmark to be compiled and installed
- Multistate error model for Lawrence Berkeley National Laboratory
- Empirical satellite channel model using the multistate error model

Remote Astronomy over Trans-Pacific ATM Satellites
Network Test Plan

Status (cont.)

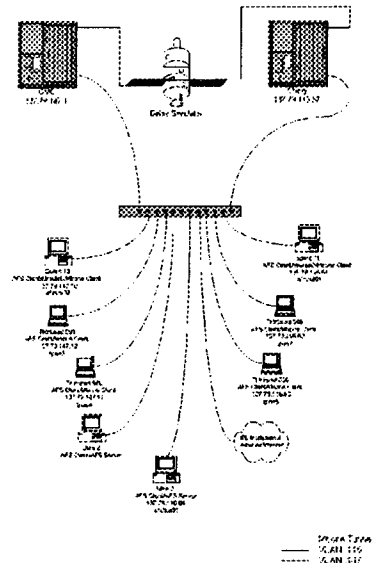
- The Andrew Benchmark
 - MakeDir: Construct a target subtree that is identical to the source subtree
 - Copy: Copy every file from the source subtree to the target subtree
 - ScanDir: Traverse the target subtree and examine the status of every file in it
 - ReadAll: Scan every byte of every file in the target subtree
 - Make: Complete and link all files in the target subtree
- Multicast-based measurement tool: *mtrace*
mtrace reports the route from a multicast source to a receiver, along with other information about that path such as per-hop loss and delay statistics. Topology discovery through *mtrace* is performed as part of the tracer tool.
 - Host
 - Loss
 - Delay

Trans-Pacific Connections



Remote Astronomy over Trans-Pacific ATM Satellites Laboratory Testbed

- Established a laboratory testbed for multicast and distributed file systems applications for the Trans-Pacific Astronomy Experiment. The testbed permits the storage of archived astronomical images and the verification of system operations between JPL and NASA Ames, GRC, GSFC, and participants in Japan.
- It will later be re-configured as an operational platform for conducting remote astronomical observations, collaborative discussions, and distributed systems studies.



Remote Astronomy over Trans-Pacific ATM Satellites Local AFS Tests

- Laboratory-based Andrew Benchmark Test Results

**TABLE 1
ANDREW BENCHMARK OF TPAE SERVER
AS FUNCTIONS OF SATELLITE DELAY AND SERVER
LOADING**

*(Average and standard deviation in
minutes)*

	1 Client	2 Clients	4 Clients	6 Clients	8 Clients
No delay	1.4 (0.1)	1.5 (0.2)	1.4 (0.1)	1.5 (0.1)	1.5 (0.1)
300 ms	7.1 (0.1)	7.2 (0.2)	7.2 (0.3)	7.5 (0.4)	7.6 (0.6)
600 ms	13.0 (0.3)	13.2 (0.4)	13.2 (0.4)	13.4 (1.1)	13.6 (1.1)
900 ms	18.2 (1.3)	18.6 (1.1)	18.4 (1.0)	18.6 (1.0)	18.7 (1.2)

(Times in minutes:seconds)

	1 Client	2 Clients	4 Clients	6 Clients	8 Clients
No delay	1:24	1:30	1:24	1:30	1:30
300 ms	7:06	7:12	7:12	7:30	7:36
600 ms	13:00	13:12	13:10	13:24	13:36
900 ms	18:10	18:40	18:24	18:36	18:42

(Times in minutes)

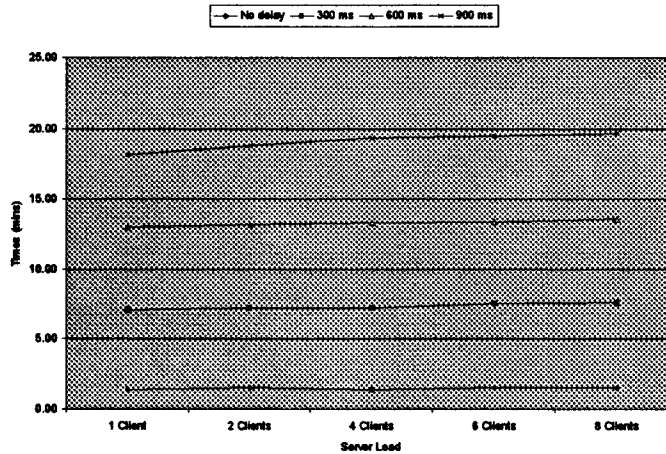
	1 Client	2 Clients	4 Clients	6 Clients	8 Clients
No delay	1.40	1.50	1.40	1.50	1.50
300 ms	7.10	7.20	7.20	7.50	7.60
600 ms	13.00	13.20	13.20	13.40	13.60
900 ms	18.20	18.60	18.40	18.50	18.70

- Verification of equipment and application software in a laboratory environment
- Obtain a baseline for which to judge the operational system's health
- Provide a basis for architectural fine-tuning
- Show the important of having replicated sites in a distributed environment
- Verify the effects of satellite delay and error on the AFS and multicast systems are acceptable
- Reduce time spent during actual trans-Pacific linkage via Intelsat
- Small variations in the number of clients, significant variations from link delays

Remote Astronomy over Trans-Pacific ATM Satellites Local AFS Tests

- Laboratory-based Andrew Benchmark Test Results using Satellite Delay Simulator

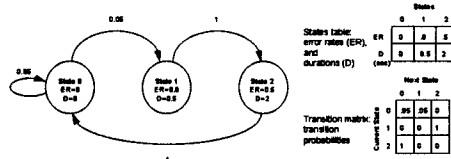
Figure 2 - TPAE Andrew Benchmark



**Remote Astronomy over Trans-Pacific ATM Satellites
Multi-state Error Model**

- Deliver in report form the source code for a multi-state error model for the Lawrence Berkeley National Laboratory's (LBNL) Network Simulator.

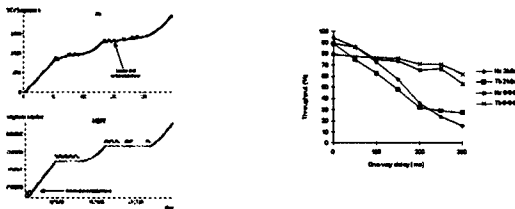
Multi-state error model permits the construction of detailed empirical or statistical channel models describing various conditions that affect a satellite link. The capability helps protocol researchers model detailed profiles of satellite channels and study their use in the global information infrastructure.



**Remote Astronomy over Trans-Pacific ATM Satellites
Empirical Link Model for Network Simulator**

- Deliver in report form an empirical satellite channel model for the LBNL Network Simulator using propagation data from NASA Advanced Communications Technology Satellite.

The simulator, augmented with channel models, would permit the extensive study of scale and protocol interaction in current and future network protocols, including congestion control, reliable multicast, multicast routing, dynamic topologies, and integrated services.



Remote Astronomy over Trans-Pacific ATM Satellites

Sample Sessions

• **The Structure of Galaxies**

Observe examples of the various types of galaxies with the TIE telescope. Compare with HST observations of similar galaxies, both nearby and very distant. May also compare with Digitized Sky Survey observations of many galaxies

• **The Lives of the Stars**

Observe a number of nebulae with the TIE telescope. Include HII regions (stellar birthplaces), planetary nebulae (death sites of low-mass stars), and supernova remnants (death sites of high-mass stars). Compare with HST observations of similar targets, both in our Galaxy and in others (e.g., the Magellanic Clouds). May also compare with Digitized Sky Survey observations of many nebulae.

• **Where are all the Stars?**

Observe a number of Galactic star clusters with the TIE telescope. Use these observations, and archival ones from HST, to account for the ~100 billion stars in the Milky Way. Also observe a smaller number of spiral galaxies with the TIE telescope to aid in understanding the larger picture.

Remote Astronomy over Trans-Pacific ATM Satellites

Sample Sessions (cont.)

• **Mt. Wilson images stored on local AFS server**

- AFS server performs synchronization to replicate the file at all locations

• **Discussion using IP-Multicast tools**

• **Post processing of images using distributed file access system possible**

- Compositing of images

• **Hubble Space Telescope archived images**

- Determined based on finalized schedule for trans-Pacific connections
- More generic images will be pre-loaded

• **Estimated 2-hour lectures**

Remote Astronomy over Trans-Pacific ATM Satellites

Demonstration

- Jan-Mar 2000
- Involve Mt. Wilson Institute, local schools (US and Japan), and Trans-Pacific Experiment participants
- Broadband satellite links with fiber optic terrestrial connections, and Asia-Pacific Advanced Network
 - Base-line for network performance comparison (Satcom and APAN)
- Facilitates academic and public participation
 - Applications available on personal computers
 - Opportunities for research

Remote Astronomy over Trans-Pacific ATM Satellites Acknowledgement

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