# NASA G7-GIBN Project

JPL

Trans-Pacific Astronomy Experiment
Project Status

Eddie Hsu
Ph: +1 818 354-3212 Fx: +1 818 393-3302
eddie.hsu@jpl.nasa.gov

Jet Propulsion Laboratory, California Institute of Technology

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
- A part of the Global Information Infrastructure-Global Interoperability for Broadband Networks Project (GII-GIBN)
  - 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

## Participation

- Global Interoperability for Broadband Networks Project, G7-GII

- Current participants (astronomy experiment):
  - AT&T
  - NASA GRC, GSFC, JPL, NREN
  - The George Washington University
  - University of Maryland
  - The Mt. Wilson Institute, in association with
    - Crossroads (CA), T. Jefferson (VA) High Schools
    - Soka High School (Japan)
  - Misato Observatory
  - Japan Ministry of Posts and Telecommunications
  - Communications Research Laboratory
  - Kokusai Denshin Denwa Co., Ltd.
  - Nippon Telegraph and Telephone
  - Intelsat/Comsat

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 Initiative/Mars Infrastructure

## 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

## 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) and/or High Performance Storage System (HPSS)



## 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 GSFC established
  - PVC assigned: (0,55)
  - NTTCP ATM level verification
- 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

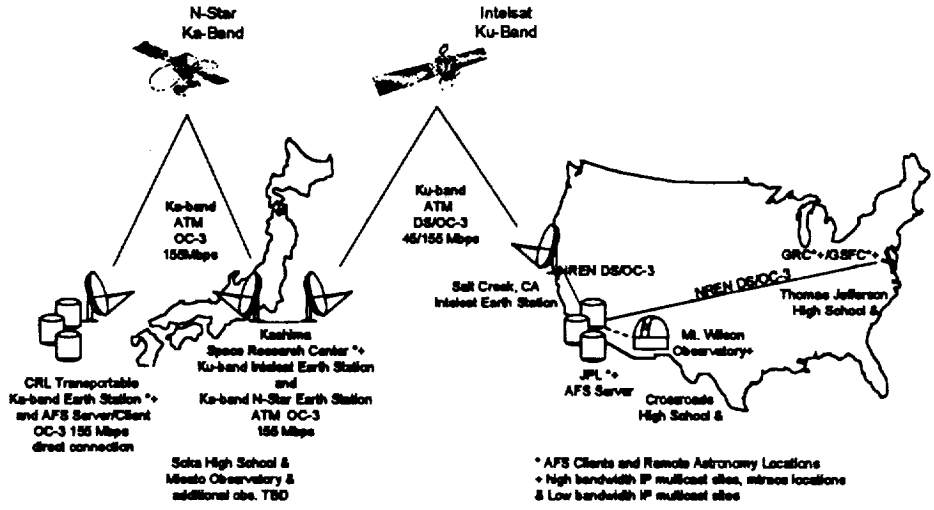
- MakeDir: Construct a target subtree that is identical to the source subtree
- Copy: Copy every file from the source subtree to the target subtree
- ScanDir: Traverse the target subtree and examine the status of every file in it
- ReadAll: Scan every byte of every file in the target subtree
- Make: 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.

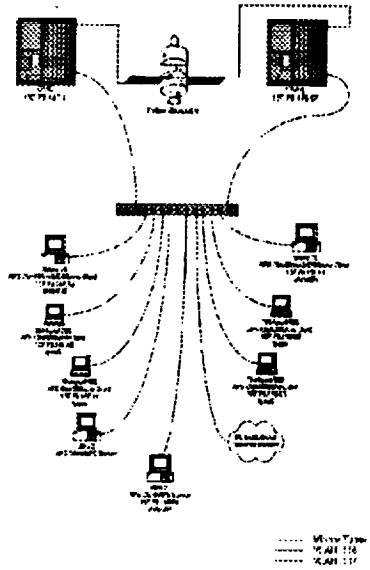
- Host
- Loss
- Delay

Trans-Pacific Connections



Remote Astronomy over Trans-Pacific ATM Satellites
Laboratory Testbed

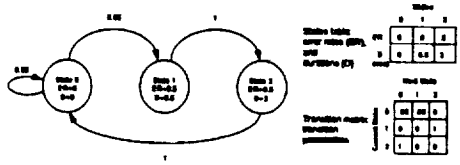
- Established a laboratory testbed for multicast and distributed file systems applications for the Trans-Pacific Astronomy Experiment. The testbed permits the storage of archived astronomical images and the verification of system operations between JPL and NASA Ames, GRC, GSFC, and participants in Japan.
- 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
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.

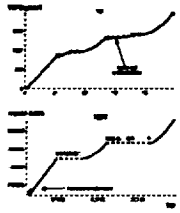
  Multi-state error model permits the construction of detailed empirical or statistical channel models describing various conditions that affect a satellite link. The capability helps protocol researchers model detailed profiles of satellite channels and study their use in the global information infrastructure.

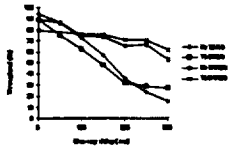


Remote Astronomy over Trans-Pacific ATM Satellites
Empirical Link Model for Network Simulator

- 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.

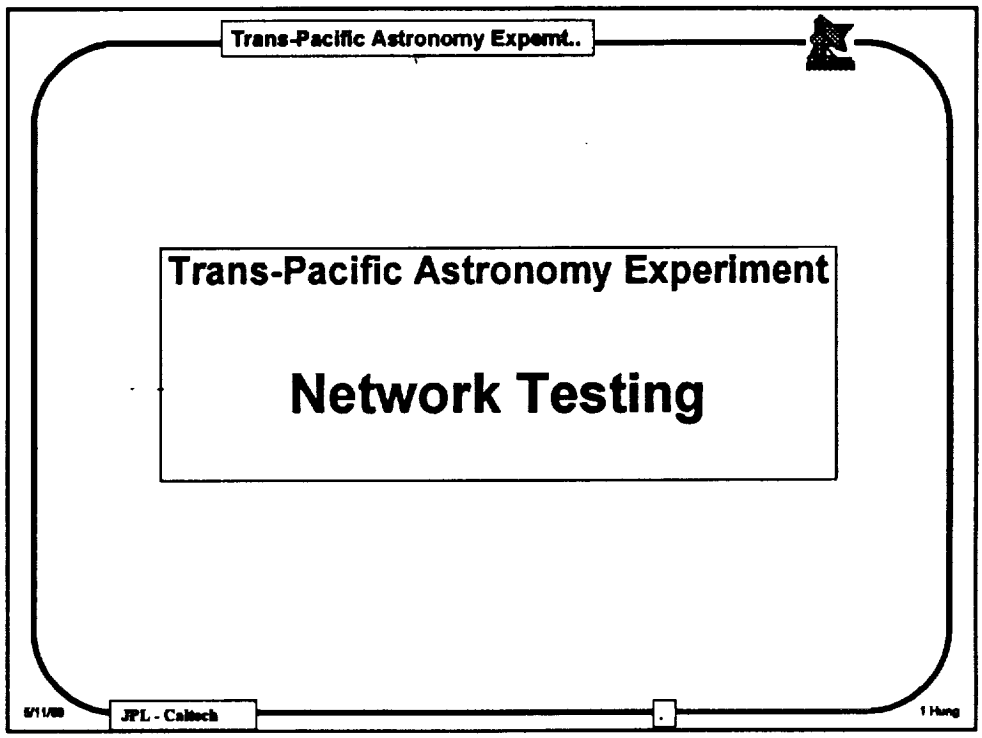
## Sample Sessions (cont.)

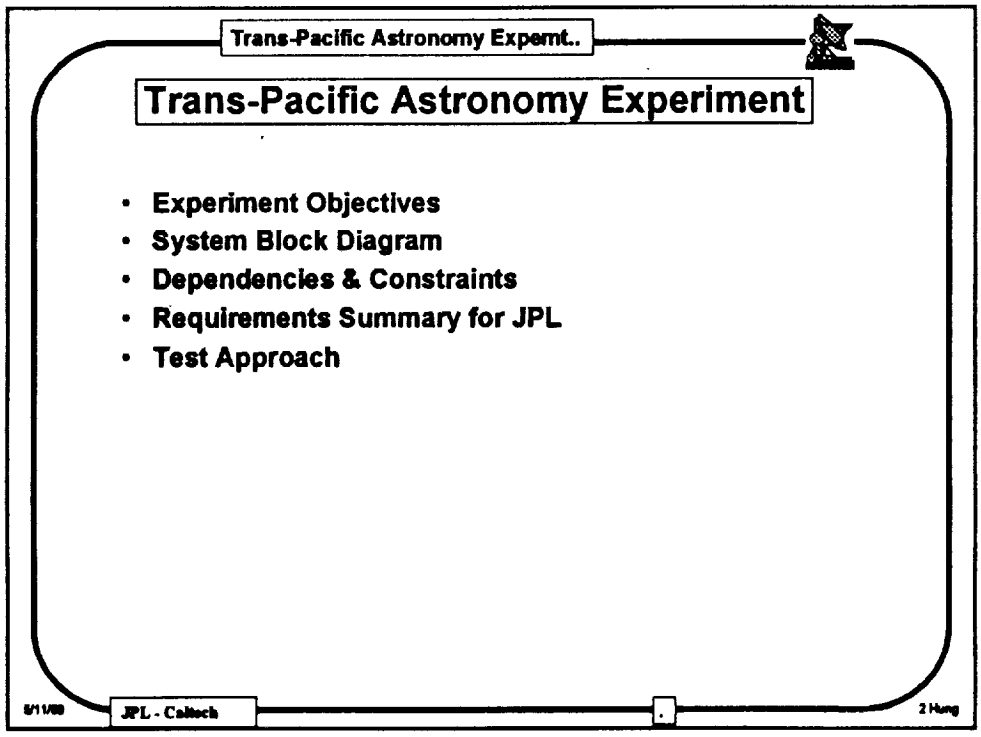
- Mt. Wilson images stored on local AFS server
  - AFS server performs synchronization to replicate the file at all locations
- Discussion using IP-Multicast tools
- Post processing of images using distributed file access system possible
  - Compositing of images
- Hubble Space Telescope archived images
  - Determined based on finalized schedule for trans-Pacific connections
  - More generic images will be pre-loaded
- Estimated 2-hour lectures

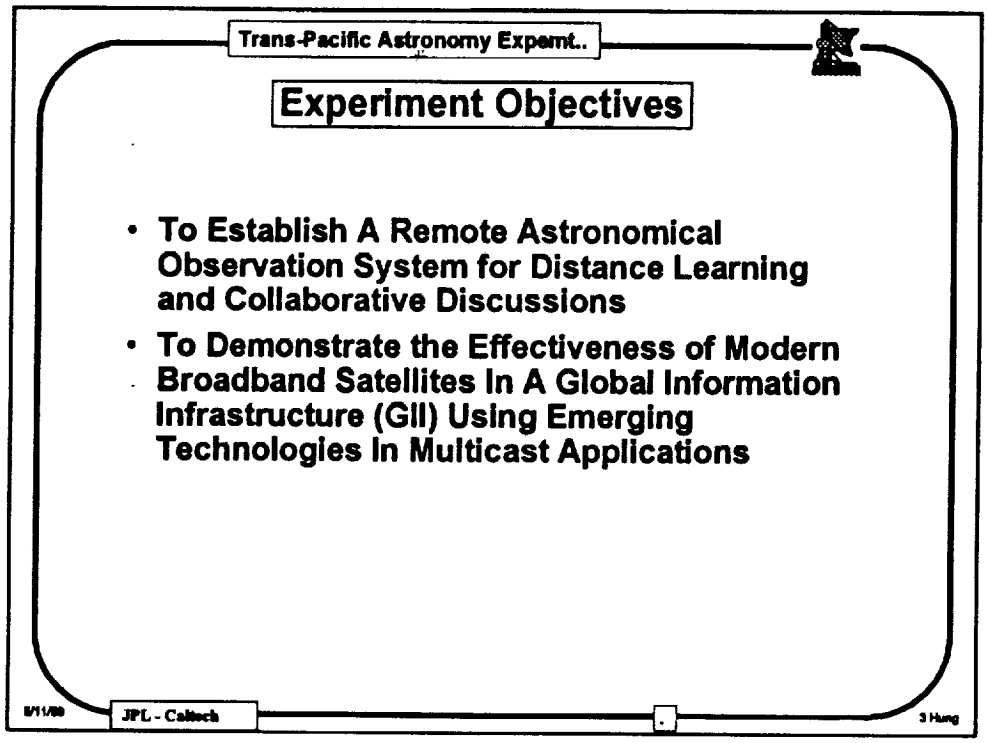


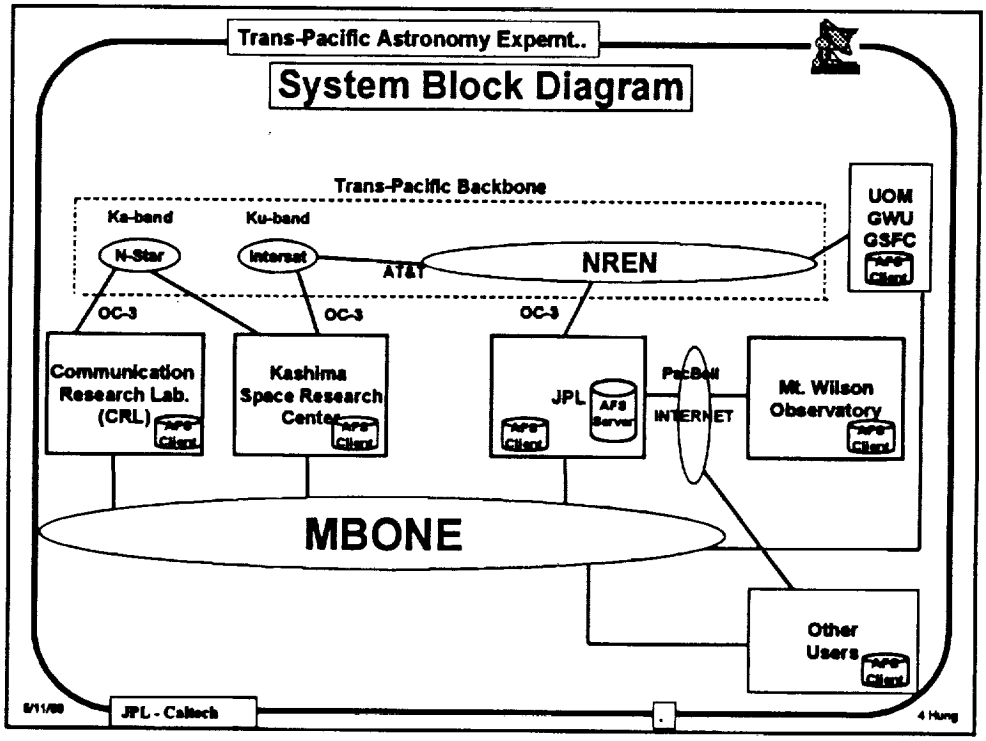
## Demonstration

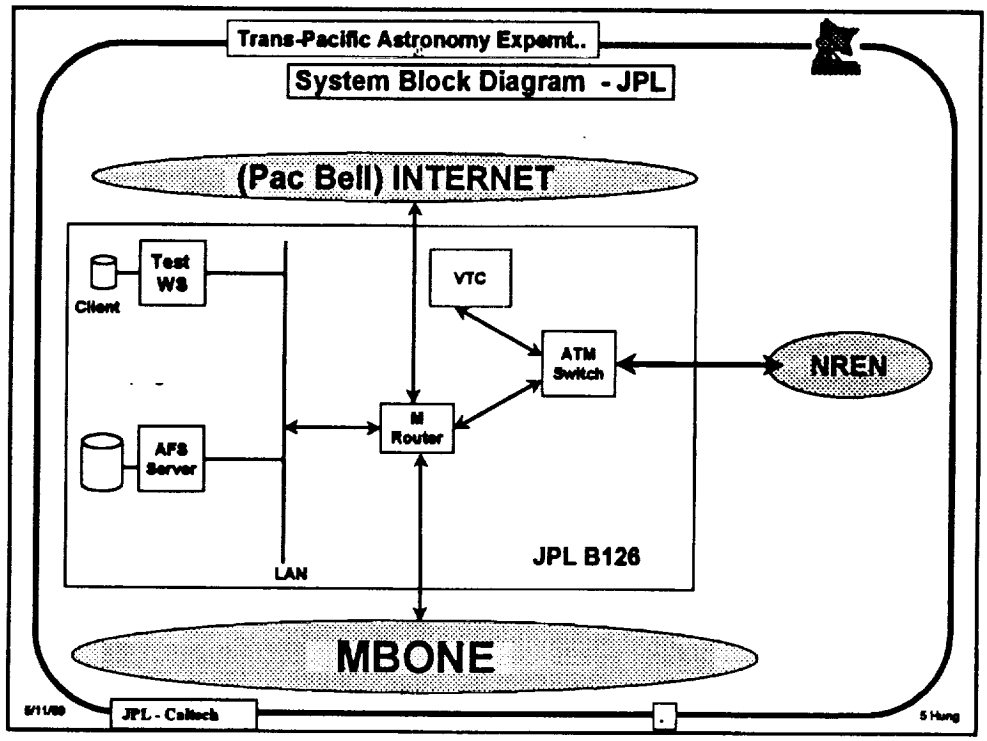
- June-Sep 1999
- Mt. Wilson Institute, local schools (US and Japan), other GIBN participants
- Broadband satellite links with terrestrial connections
- Facilitates academic and public participation
  - Applications available on personal computers
  - Opportunities for research

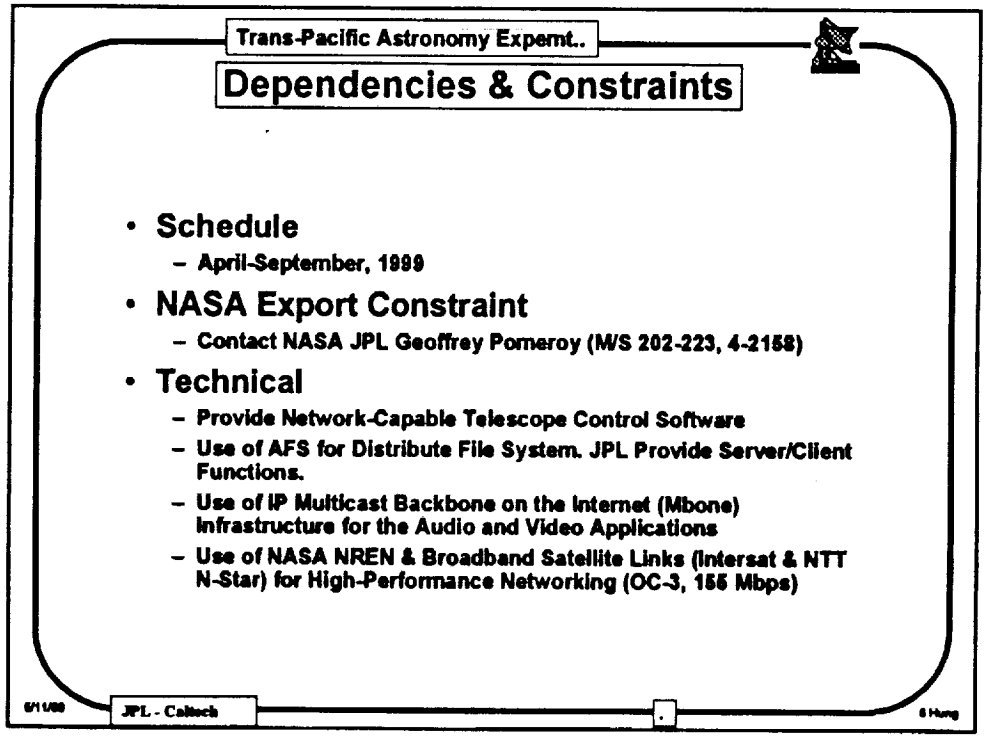

Trans-Pacific Astronomy Experm..
Trans-Pacific Astronomy Experiment
Network Testing
5/11/99
JPL - Caltech
1 Hung

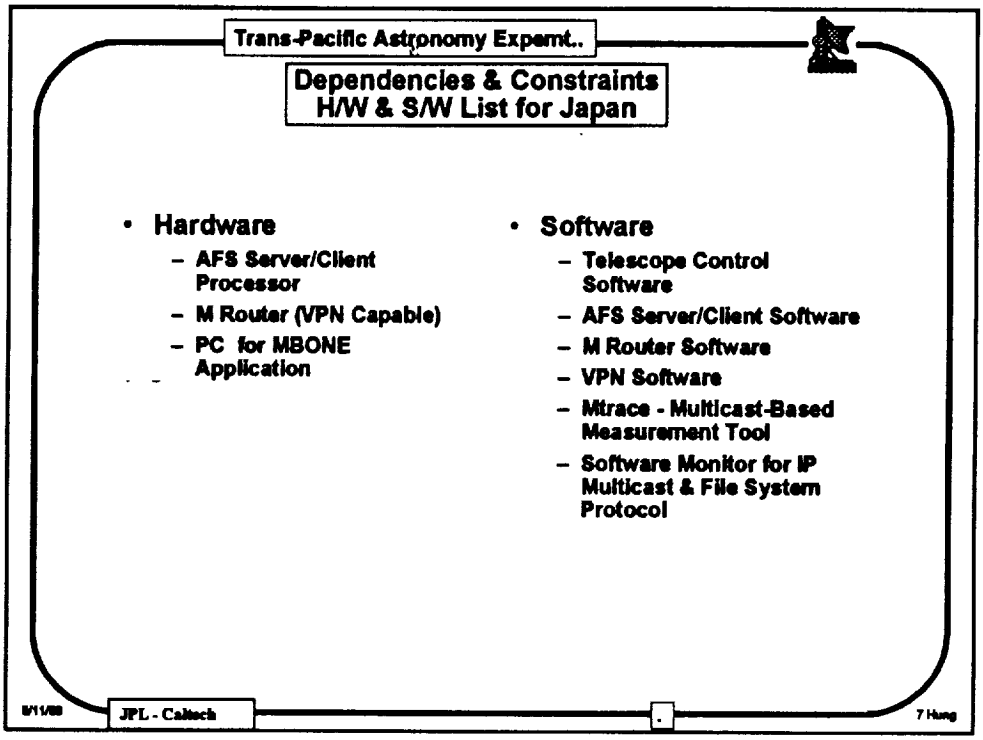

Trans-Pacific Astronomy Experm..
Trans-Pacific Astronomy Experiment
• Experiment Objectives
• System Block Diagram
• Dependencies & Constraints
• Requirements Summary for JPL
• Test Approach
5/11/99
JPL - Caltech
2 Hung

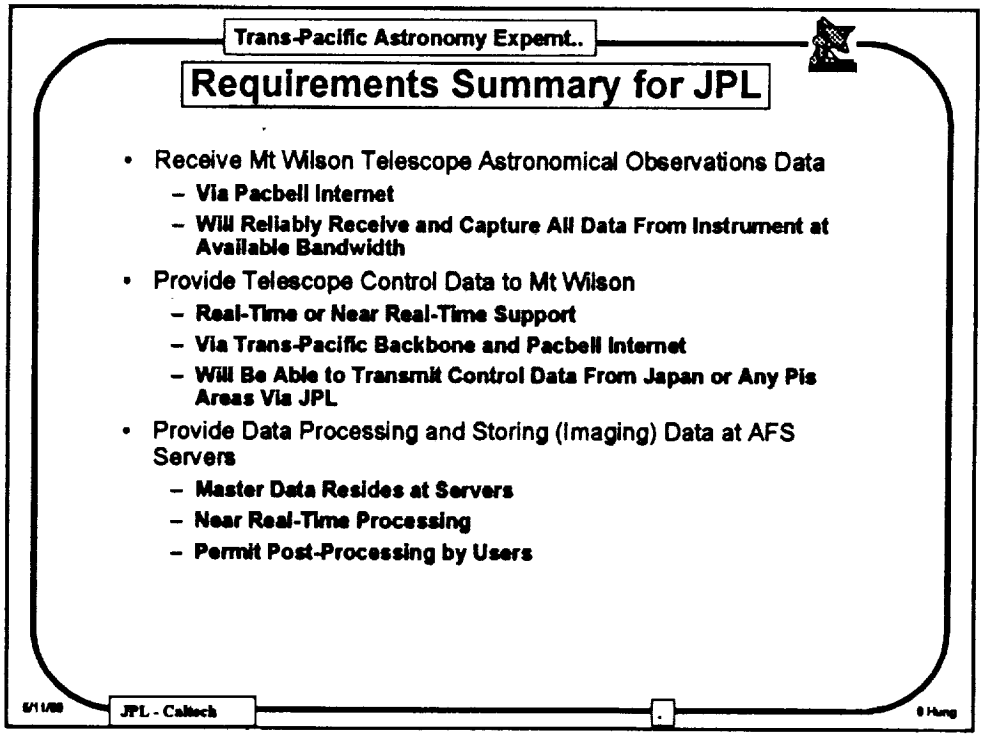

Trans-Pacific Astronomy Experm..
Experiment Objectives
• To Establish A Remote Astronomical Observation System for Distance Learning and Collaborative Discussions
• To Demonstrate the Effectiveness of Modern Broadband Satellites In A Global Information Infrastructure (GII) Using Emerging Technologies In Multicast Applications
JPL - Caltech

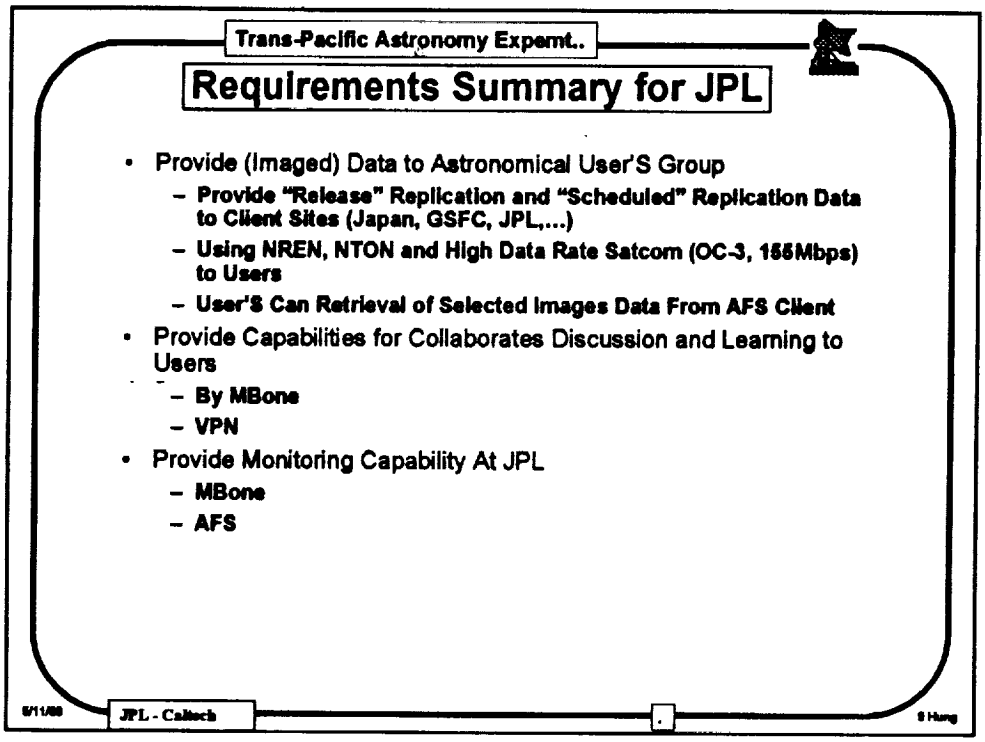

Trans-Pacific Astronomy Experm..
System Block Diagram
Trans-Pacific Backbone
Ka-band
Ku-band
N-Star
Intelsat
AT&T
NREN
UOM
GWU
GSFC
OC-3
OC-3
OC-3
Communication Research Lab. (CRL)
Kashima Space Research Center
JPL
AFS Server
PacBell
INTERNET
Mt. Wilson Observatory
MBONE
Other Users
JPL - Caltech

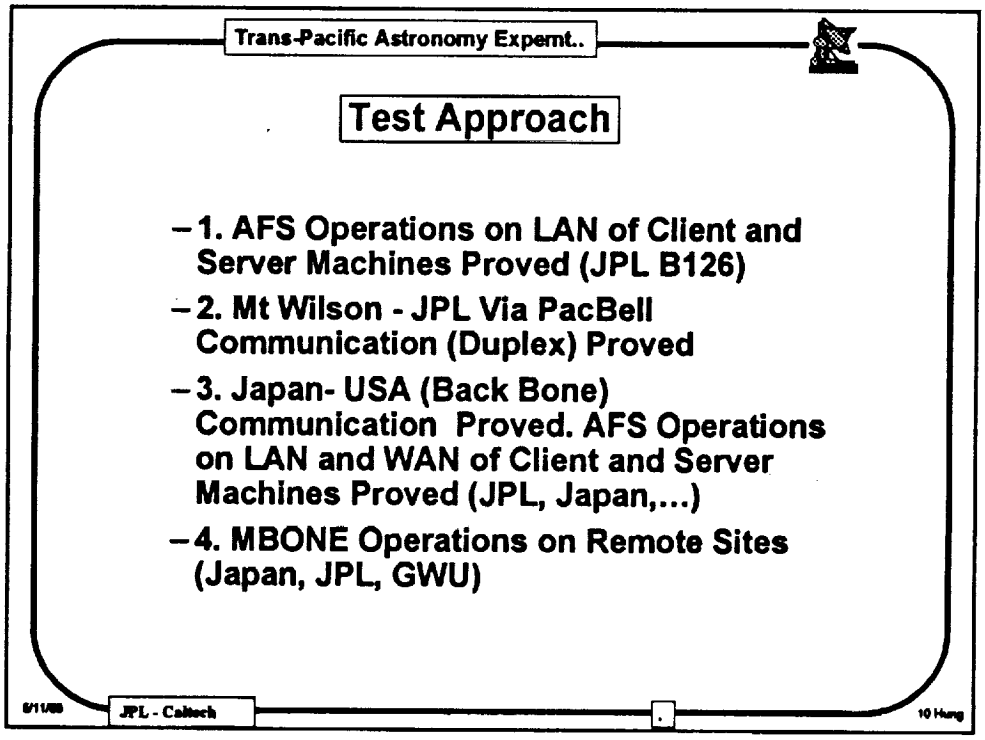

Trans-Pacific Astronomy Experm..
System Block Diagram - JPL
(Pac Bell) INTERNET
Test WS
Client
VTC
ATM Switch
NREN
M Router
AFS Server
LAN
JPL B126
MBONE
JPL - Caltech
5 Hung

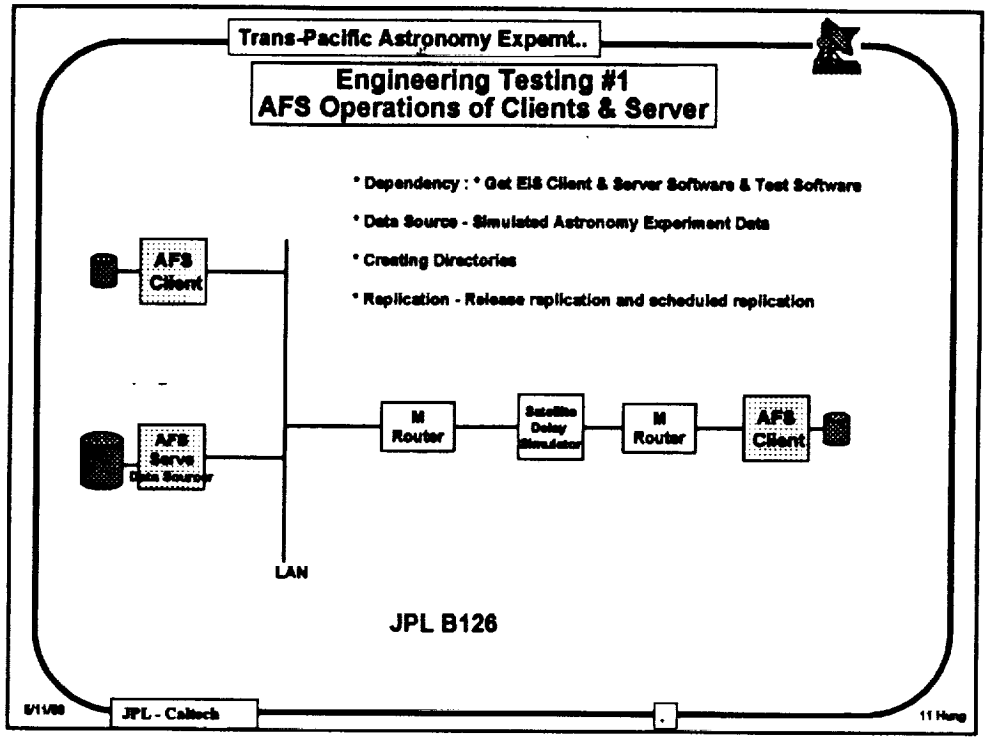

Trans-Pacific Astronomy Experm..
Dependencies & Constraints
• Schedule
– April-September, 1999
• NASA Export Constraint
– Contact NASA JPL Geoffrey Pomeroy (M/S 202-223, 4-2158)
• Technical
– Provide Network-Capable Telescope Control Software
– Use of AFS for Distribute File System. JPL Provide Server/Client Functions.
– Use of IP Multicast Backbone on the Internet (Mbone) Infrastructure for the Audio and Video Applications
– Use of NASA NREN & Broadband Satellite Links (Intersat & NTT N-Star) for High-Performance Networking (OC-3, 155 Mbps)
JPL - Caltech
6 Hung

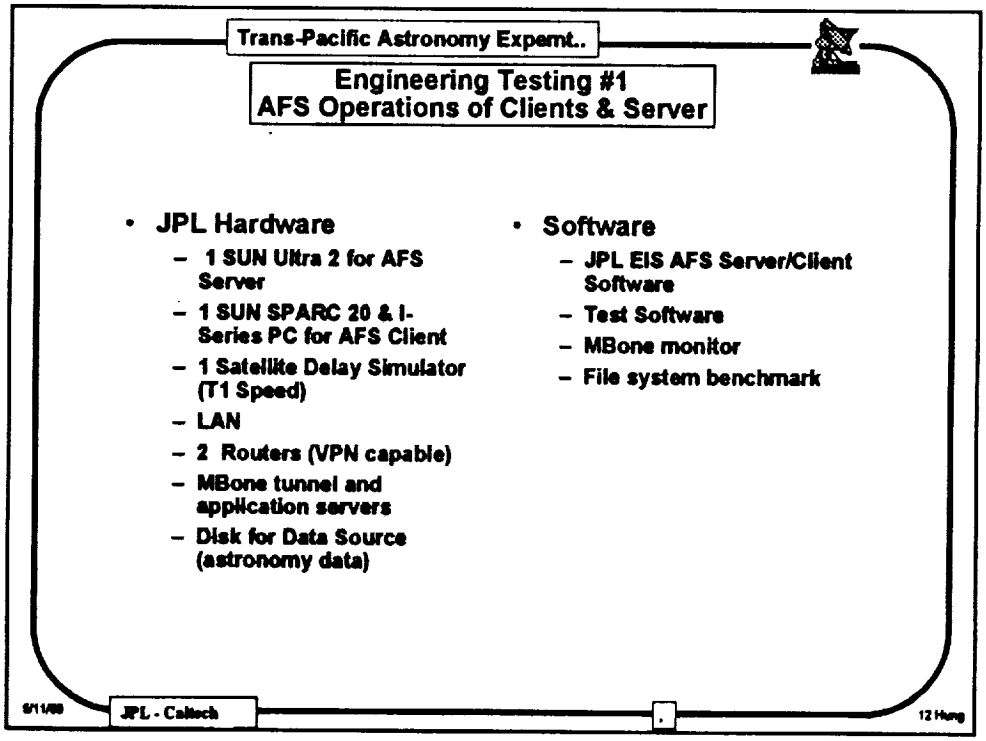

Trans-Pacific Astronomy Experm..
Dependencies & Constraints
H/W & S/W List for Japan
• Hardware
– AFS Server/Client Processor
– M Router (VPN Capable)
– PC for MBONE Application
• Software
– Telescope Control Software
– AFS Server/Client Software
– M Router Software
– VPN Software
– Mtrace - Multicast-Based Measurement Tool
– Software Monitor for IP Multicast & File System Protocol
JPL - Caltech
7 Hung

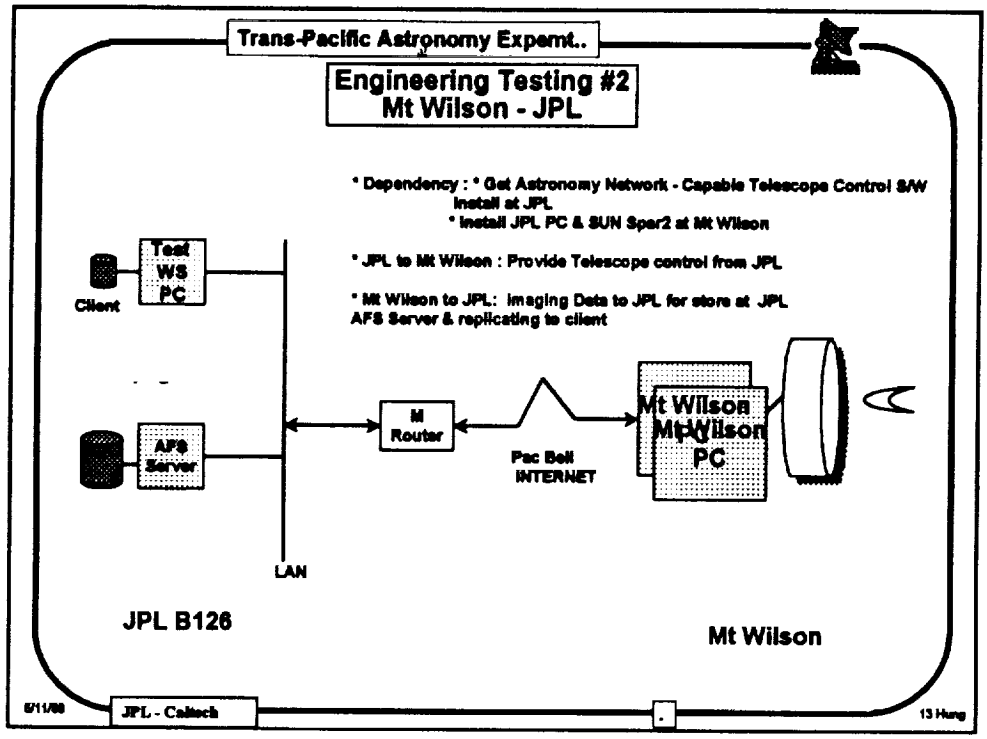

Trans-Pacific Astronomy Experm..
Requirements Summary for JPL
• Receive Mt Wilson Telescope Astronomical Observations Data
– Via Pacbell Internet
– Will Reliably Receive and Capture All Data From Instrument at Available Bandwidth
• Provide Telescope Control Data to Mt Wilson
– Real-Time or Near Real-Time Support
– Via Trans-Pacific Backbone and Pacbell Internet
– Will Be Able to Transmit Control Data From Japan or Any Pis Areas Via JPL
• Provide Data Processing and Storing (Imaging) Data at AFS Servers
– Master Data Resides at Servers
– Near Real-Time Processing
– Permit Post-Processing by Users
JPL - Caltech
8 Hung

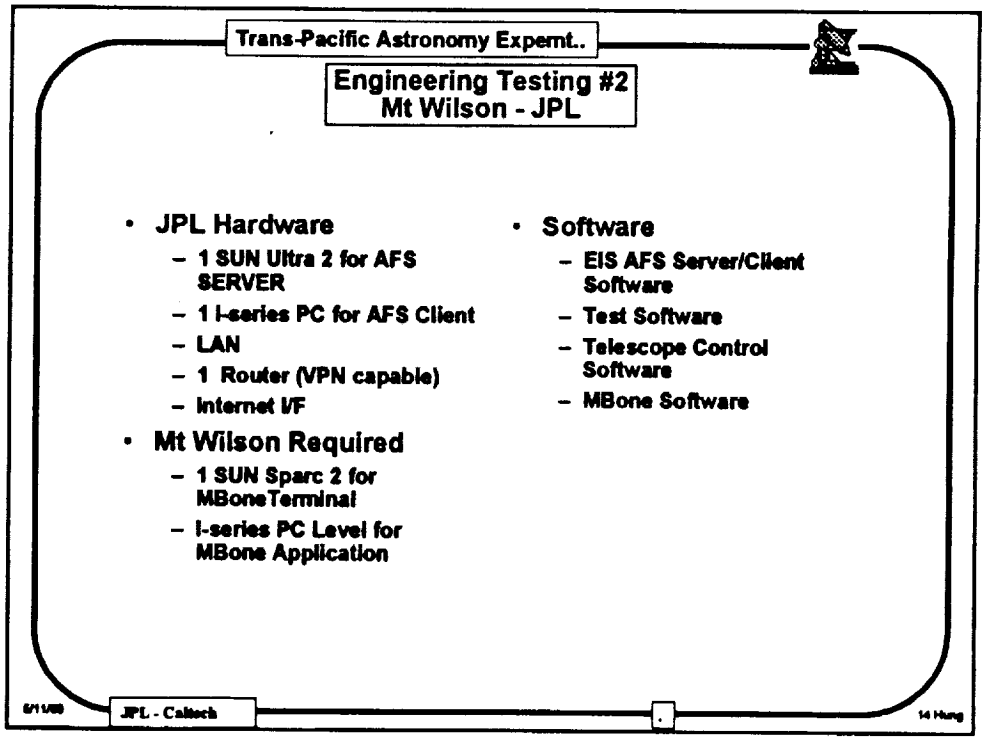

Trans-Pacific Astronomy Experm..
Requirements Summary for JPL
• Provide (Imaged) Data to Astronomical User'S Group
– Provide "Release" Replication and "Scheduled" Replication Data to Client Sites (Japan, GSFC, JPL,...)
– Using NREN, NTON and High Data Rate Satcom (OC-3, 155Mbps) to Users
– User'S Can Retrieval of Selected Images Data From AFS Client
• Provide Capabilities for Collaborates Discussion and Learning to Users
– By MBone
– VPN
• Provide Monitoring Capability At JPL
– MBone
– AFS
JPL - Caltech

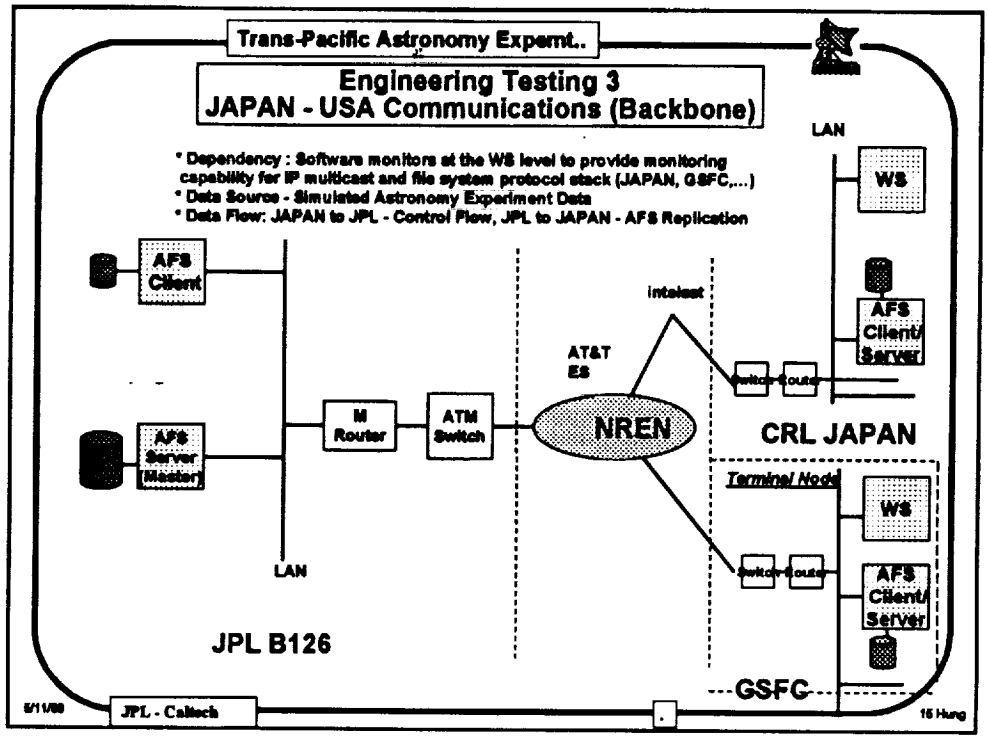

Trans-Pacific Astronomy Experm..
Test Approach
–1. AFS Operations on LAN of Client and Server Machines Proved (JPL B126)
–2. Mt Wilson - JPL Via PacBell Communication (Duplex) Proved
–3. Japan- USA (Back Bone) Communication Proved. AFS Operations on LAN and WAN of Client and Server Machines Proved (JPL, Japan,...)
–4. MBONE Operations on Remote Sites (Japan, JPL, GWU)
JPL - Caltech

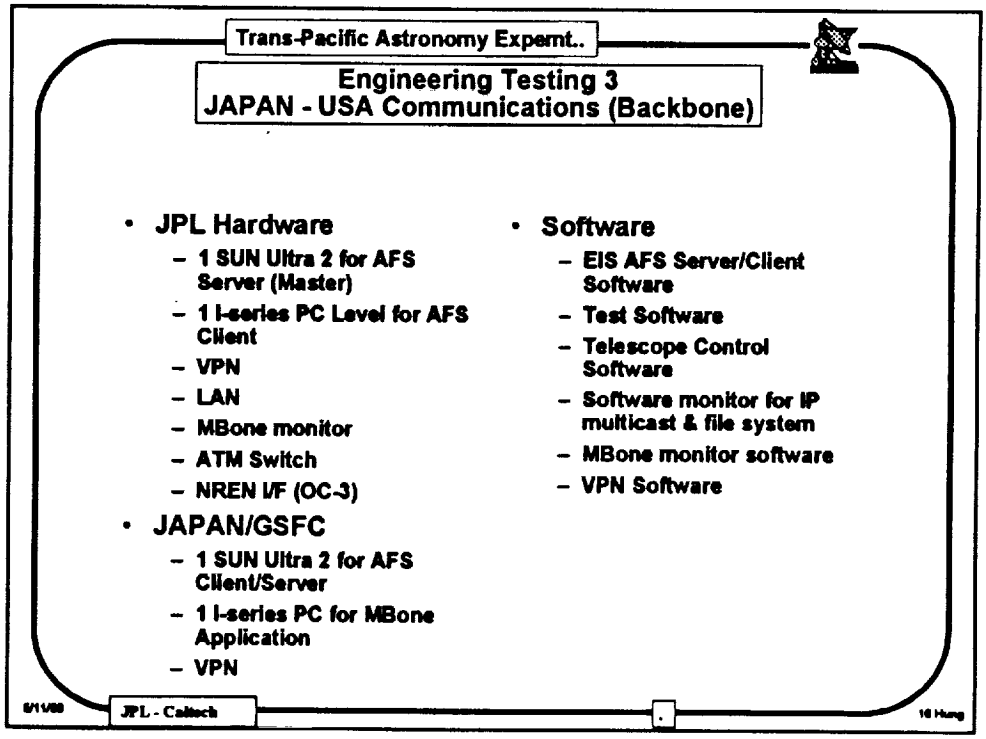

Trans-Pacific Astronomy Experimt..
Engineering Testing #1
AFS Operations of Clients & Server
* Dependency : * Get EIS Client & Server Software & Test Software
* Data Source - Simulated Astronomy Experiment Data
* Creating Directories
* Replication - Release replication and scheduled replication
AFS Client
AFS Server
Data Source
M Router
Satellite Delay Simulator
M Router
AFS Client
LAN
JPL B126
5/11/99
JPL - Caltech
11 Hung

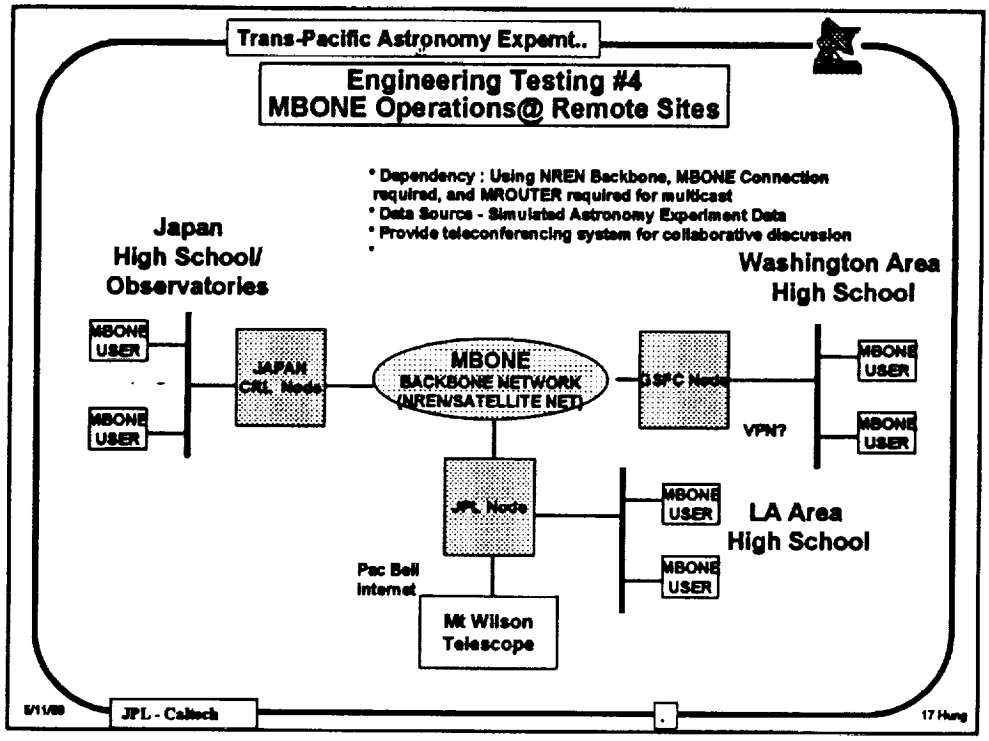

Trans-Pacific Astronomy Experimt..
Engineering Testing #1
AFS Operations of Clients & Server
• JPL Hardware
– 1 SUN Ultra 2 for AFS Server
– 1 SUN SPARC 20 & I-Series PC for AFS Client
– 1 Satellite Delay Simulator (T1 Speed)
– LAN
– 2 Routers (VPN capable)
– MBone tunnel and application servers
– Disk for Data Source (astronomy data)
• Software
– JPL EIS AFS Server/Client Software
– Test Software
– MBone monitor
– File system benchmark
5/11/99
JPL - Caltech
12 Hung

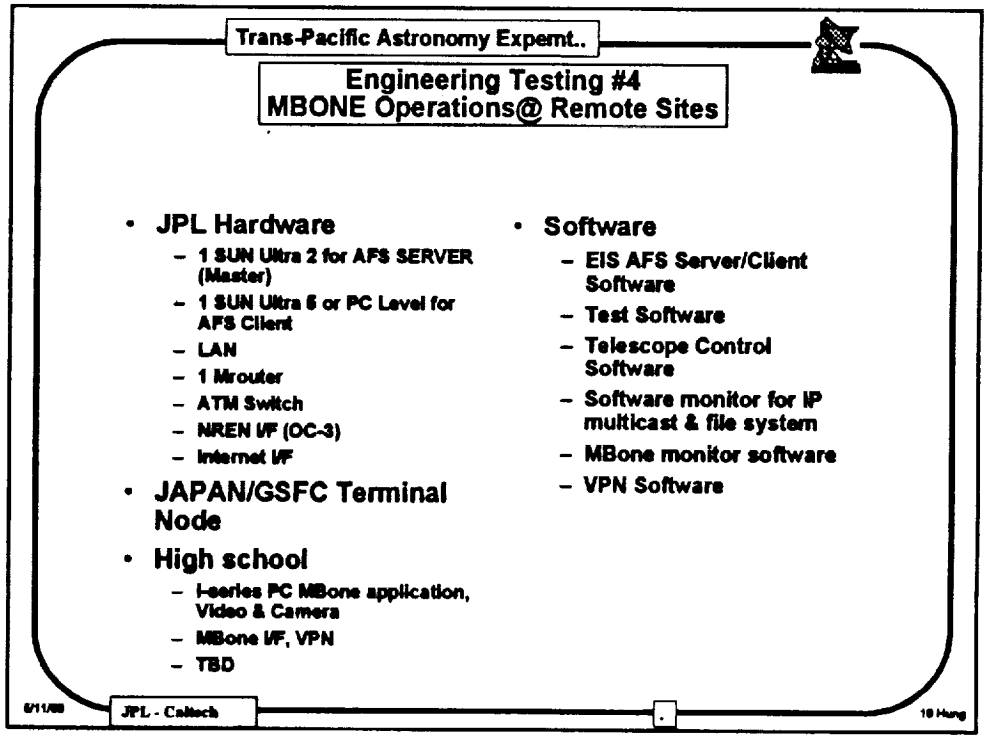

Trans-Pacific Astronomy Experm..
Engineering Testing #2
Mt Wilson - JPL
* Dependency : * Get Astronomy Network - Capable Telescope Control S/W Install at JPL
* Install JPL PC & SUN Sparc2 at Mt Wilson
* JPL to Mt Wilson : Provide Telescope control from JPL
* Mt Wilson to JPL: Imaging Data to JPL for store at JPL AFS Server & replicating to client
Test WS PC
Client
AFS Server
M Router
Pac Bell INTERNET
Mt Wilson MtWilson PC
LAN
JPL B126
Mt Wilson
JPL - Caltech
13 Hung


Trans-Pacific Astronomy Experm..
Engineering Testing #2
Mt Wilson - JPL
• JPL Hardware
– 1 SUN Ultra 2 for AFS SERVER
– 1 I-series PC for AFS Client
– LAN
– 1 Router (VPN capable)
– Internet I/F
• Mt Wilson Required
– 1 SUN Sparc 2 for MBoneTerminal
– I-series PC Level for MBone Application
• Software
– EIS AFS Server/Client Software
– Test Software
– Telescope Control Software
– MBone Software
JPL - Caltech
14 Hung


Trans-Pacific Astronomy Experm..
Engineering Testing 3
JAPAN - USA Communications (Backbone)
* Dependency : Software monitors at the WS level to provide monitoring capability for IP multicast and file system protocol stack (JAPAN, GSFC,...)
* Data Source - Simulated Astronomy Experiment Data
* Data Flow: JAPAN to JPL - Control Flow, JPL to JAPAN - AFS Replication
LAN
WS
AFS Client
Intelsat
AT&T ES
AFS Client/ Server
M Router
ATM Switch
NREN
CRL JAPAN
AFS Server (Master)
Terminal Node
WS
LAN
AFS Client/ Server
JPL B126
GSFC
JPL - Caltech


Trans-Pacific Astronomy Experm..
Engineering Testing 3
JAPAN - USA Communications (Backbone)
• JPL Hardware
– 1 SUN Ultra 2 for AFS Server (Master)
– 1 I-series PC Level for AFS Client
– VPN
– LAN
– MBone monitor
– ATM Switch
– NREN I/F (OC-3)
• JAPAN/GSFC
– 1 SUN Ultra 2 for AFS Client/Server
– 1 I-series PC for MBone Application
– VPN
• Software
– EIS AFS Server/Client Software
– Test Software
– Telescope Control Software
– Software monitor for IP multicast & file system
– MBone monitor software
– VPN Software
JPL - Caltech


Trans-Pacific Astronomy Experiment..
Engineering Testing #4
MBONE Operations@ Remote Sites
* Dependency : Using NREN Backbone, MBONE Connection required, and MROUTER required for multicast
* Data Source - Simulated Astronomy Experiment Data
* Provide teleconferencing system for collaborative discussion
Japan
High School/
Observatories
Washington Area
High School
MBONE USER
MBONE USER
JAPAN CRL Node
MBONE
BACKBONE NETWORK
(NREN/SATELLITE NET)
GSFC Node
VPN?
MBONE USER
MBONE USER
JPL Node
MBONE USER
MBONE USER
LA Area
High School
Pac Bell
Internet
Mt Wilson
Telescope
JPL - Caltech
17 Hung


Trans-Pacific Astronomy Experiment..
Engineering Testing #4
MBONE Operations@ Remote Sites
• JPL Hardware
– 1 SUN Ultra 2 for AFS SERVER (Master)
– 1 SUN Ultra 5 or PC Level for AFS Client
– LAN
– 1 Mrouter
– ATM Switch
– NREN I/F (OC-3)
– Internet I/F
• JAPAN/GSFC Terminal Node
• High school
– I-series PC MBone application, Video & Camera
– MBone I/F, VPN
– TBD
• Software
– EIS AFS Server/Client Software
– Test Software
– Telescope Control Software
– Software monitor for IP multicast & file system
– MBone monitor software
– VPN Software
JPL - Caltech
18 Hung