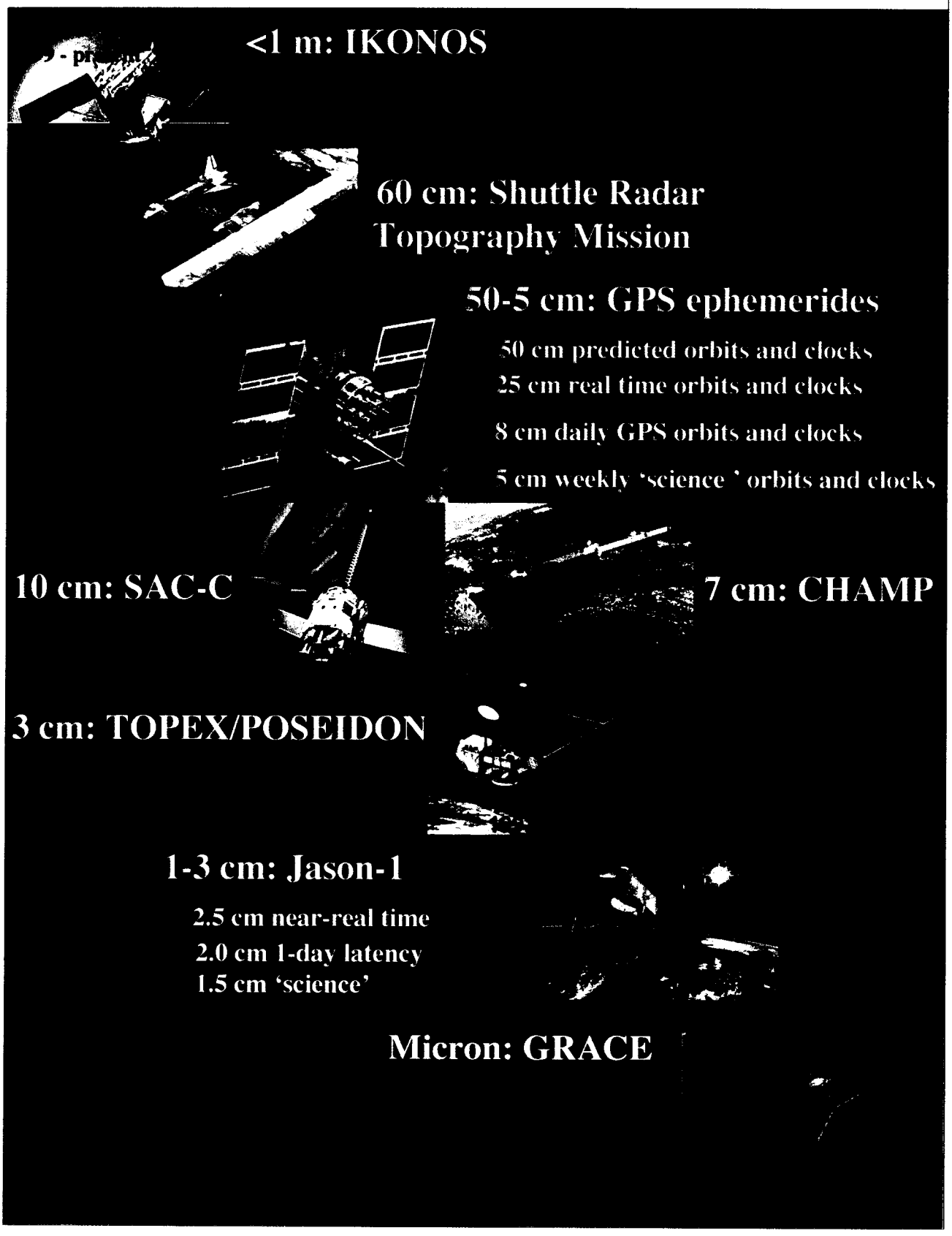
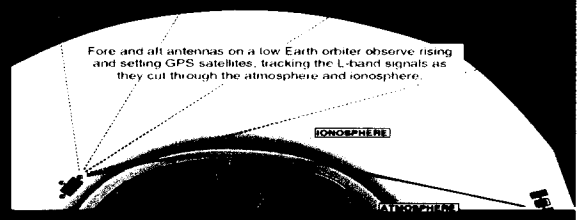
PRECISE TRACKING SYSTEMS FROM METER TO MICRON



NEW FRONTIERS IN GPS TECHNOLOGY, RADIO METRIC TRACKING, AND RADIO SCIENCE

Atmospheric sounding with GPS



Ocean altimetry with GPS Reflected signals

Primary Atomic Reference Clock in Space (PARCS)

Astrometry and deep space navigation with very large baseline interferometry

Formation flying instruments and technology

Autonomous Formation Flyer (AFF)
Constellation Communications and Navigation Transceiver (CCNT)

Advanced concepts for the next generation GNSS

Autonomous GPS sensorcraft concepts

DISTINGUISHED TRACK RECORD OF GPS TECHNOLOGY LEADERSHIP

1981: First codeless pseudorange GPS receiver (SERIES)

1986: Introduced reduced dynamic technique for precise orbit determination

1986-present: Precise GPS orbits are estimated routinely

1986: First dual frequency, code codeless geodetic-quality GPS receiver (Rogue)

1991: First civil global GPS network (GGN)

1992: First precision GPS receiver in space (TOPEX/POSEIDON)

1992: First precise GPS-based orbits of a satellite - 2.5 cm radial accuracy (TOPEX/POSEIDON)

1994: Wide Area Augmentation System design (patented)

1995: Real Time GIPSY (RTG) software selected as prototype for WAAS

1995: First GPS flight atmospheric occultation receiver (the TurboStar)

1995: Yaw bias inserted on GPS satellites to improve yaw attitude management and modeling

1998: New and improved GPS solar pressure model (GSPM)

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2000: First to provide 30 cm GPS orbits in real time

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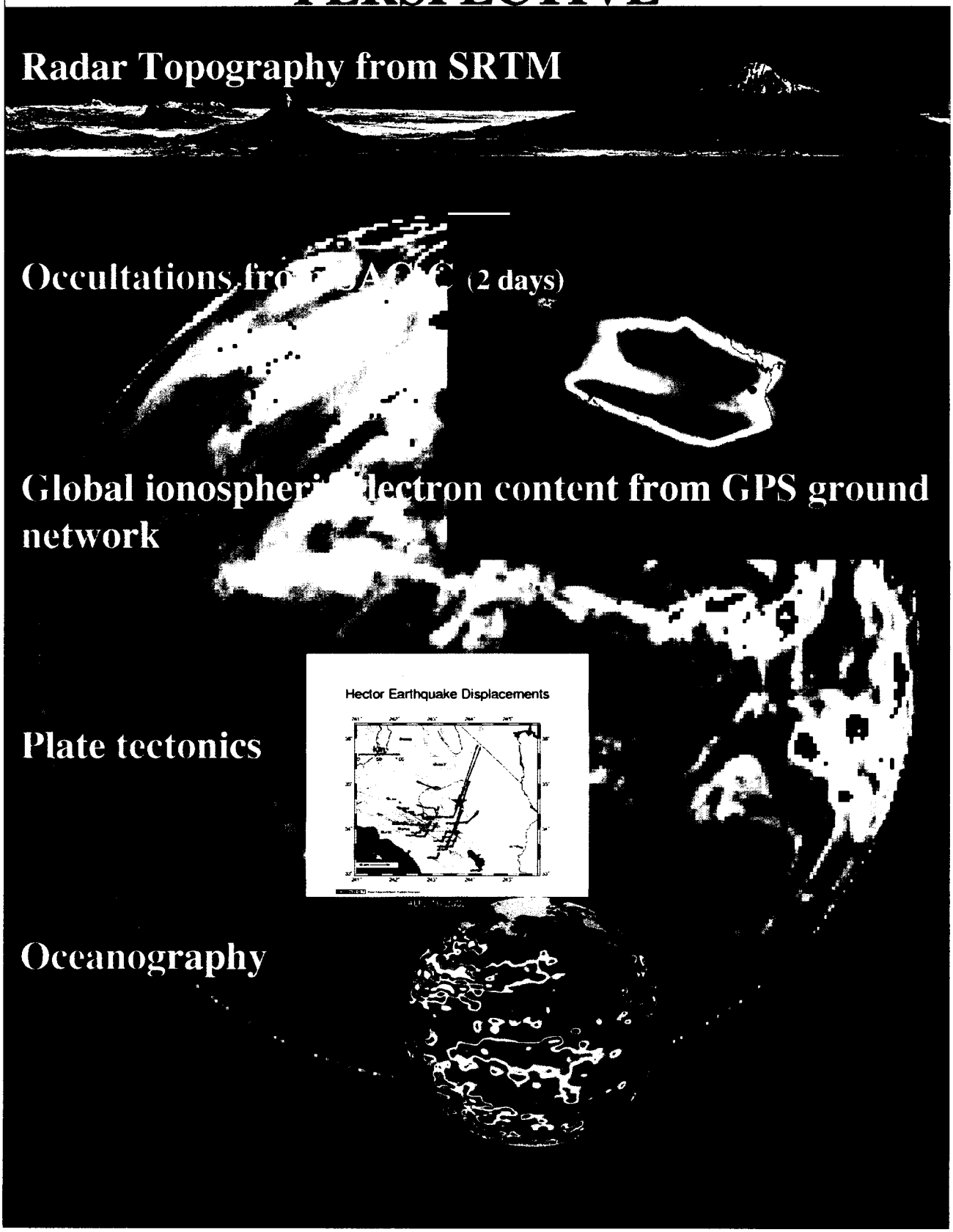
2002: First micron-level cross link ranging in E)

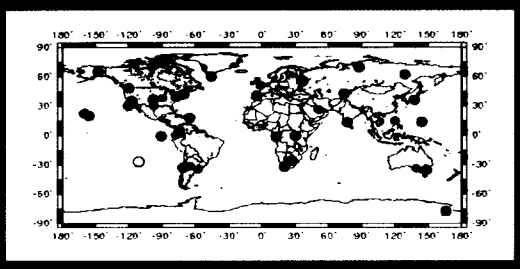
2002: Six operational GPS receivers in space; 30 flight years of operation without failure

REMOTE SENSING AND EARTH SCIENCE: PRODUCT ORIENTED PERSPECTIVE



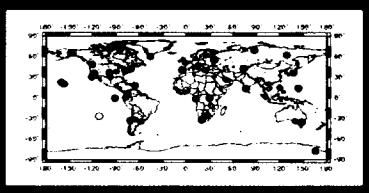
INTERNET-BASED ARCHITECTURE: RELIABILITY THROUGH REDUNDANCY

Seamless Global Coverage



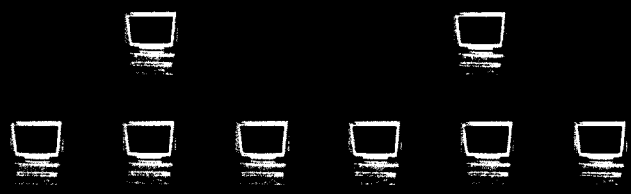
Robust Network Architecture

- Multiple Operation Centers
- Dynamic network configuration
- Automatic data rerouting



Primary Operation Centers

Secondary Operation Centers



Real Time GIPSY (RTG) Orbit Determination Software

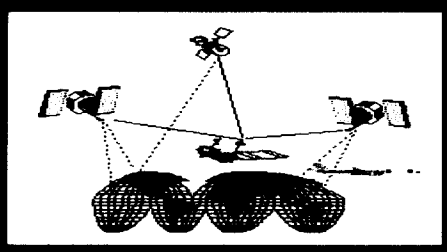
- Patented state space orbit determination approach
- Complete and accurate models for GPS satellites and navigation signal
- Orbit and clock corrections are globally and uniformly valid

Multiple Channels for Dissemination of Differential Corrections

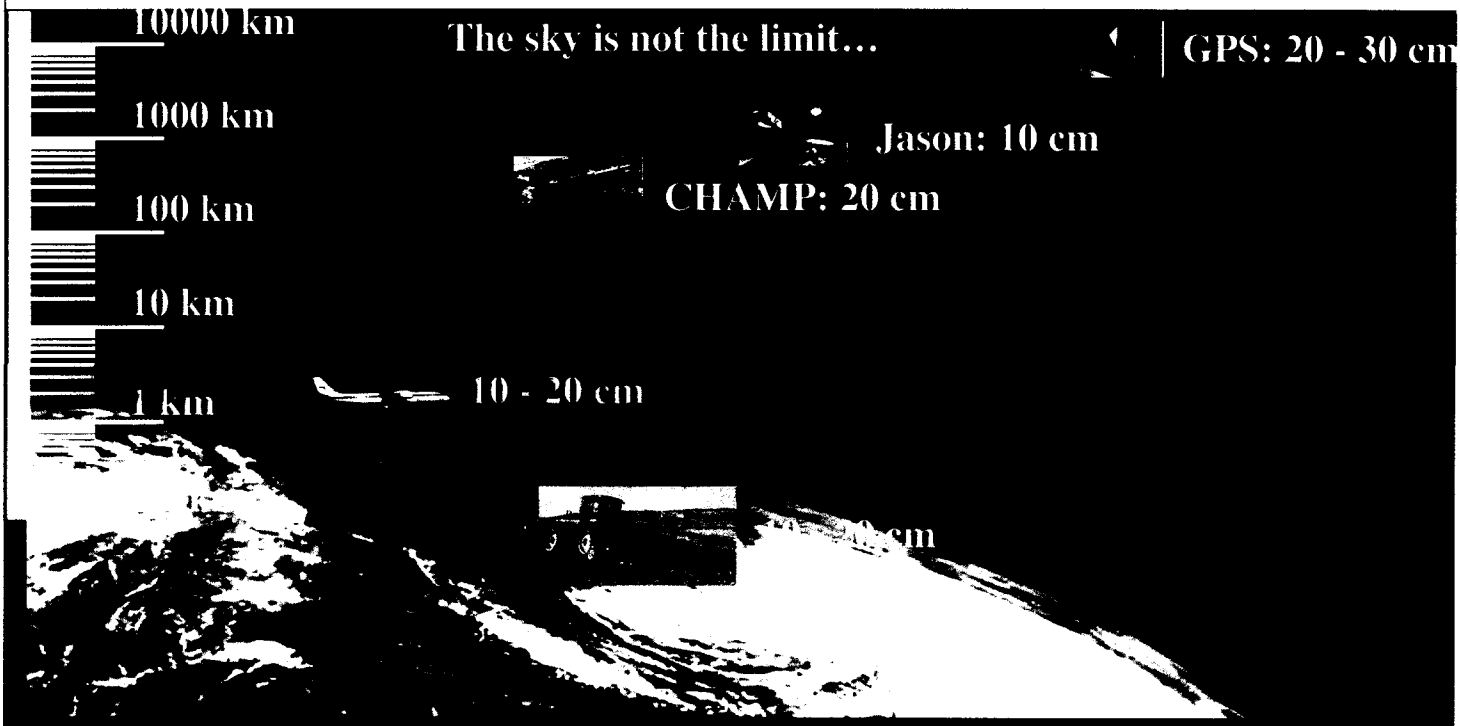
- Inmarsat global beams (through NAVCOM)
- Modem and Iridium channels
- TCP and UDP Internet clients

Sophisticated End User Software for 10 cm Positioning

- Real Time GIPSY (RTG) software
- Terrestrial, airborne, and space applications



THE MOST ACCURATE GLOBAL REAL TIME POSITIONING SYSTEM



Flexible Configuration - Uncompromising Performance

Internet

Real time positioning of the JPLM site, JPL, California

Inmarsat (NAVCOM)

Flight tests with the NASA DC-8 Over California, Colorado, and the Great Lakes

Iridium/Internet

Flight tests with the NASA P-3 Over Greenland

10 cm RMS Horizontal accuracy

20 cm RMS Vertical Accuracy

More Than Just Positioning

- Sub-nanosecond time transfer
- Sub-centimeter tropospheric delays
- GPS integrity monitoring
- Global ionospheric weather

Performance Monitoring in the Public Domain

DATA

Operational Reliability

Uncompromising Accuracy

Real time data products:

- GPS reference station data
- GPS differential corrections
- GPS broadcast ephemerides
- Media calibrations (troposphere, ionosphere)
- Site position monitoring
- Clock bias and frequency monitoring
- GPS Integrity monitoring

Near real time data products (sub-hourly to daily):

- Low Earth satellite orbits (TOPEX, Jason, GRACE)
- Sea surface height
- Earth orientation parameters

Predicted satellite orbits

Automatic GIPSY (ag) e-mail positioning services

System engineering and analysis

- Tracking systems design
- Simulations
- System integration and testing

SOFTWARE

Powerful Software Tools for GNSS Applications

GIPSY-OASIS II

Advanced GPS positioning and tracking systems analysis and simulations

Real Time GIPSY (RTG)

The accuracy of GIPSY in a compact form for real time applications

Real Time Network Transfer (RTNT):

Optimized data compression and communication for GPS reference site operations

Internet-based Global Differential GPS (IGDG):

RTG + RTNT =

The software that drives NASA's Global Differential GPS System

NASA software of the year AWARD

IGDG

Visualization and Analysis Package for Orbiting Systems (VAPORS):

Monte Carlo simulation, visualization, and animation for communications-navigation constellations

Global Ionospheric Map (GIM) & Real Time Ionosphere (RTI)

HARDWARE

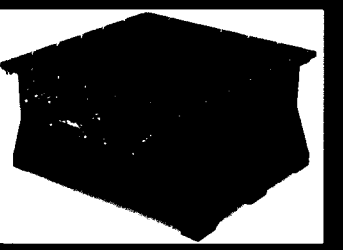
Advanced GPS Receivers for the Most Demanding Applications

Global Differential GPS Aviation Package

- 19" rack mounted chassis
- Inmarsat (NAVCOM)
  or
  Iridium communications
- Pressure transducer
- Configurable GPS engine

BlackJack family of space-borne receivers

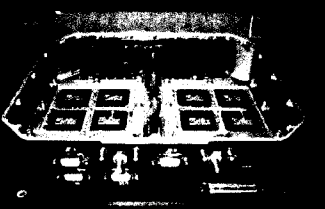
- Single antenna layout for Jason, IceSat, VCL, and SRTM

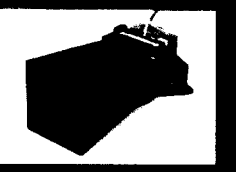


- 4 antenna layout for CHAMP and SAC-C
- Internally redundant
- Occultation capable
- Reflections capable

Blackjack receiver with integrated Star Tracker

- GRACE Class
- Cross-link capable
- Occultation capable
- Reflections capable
- 2 arcsec star camera
  Attitude @ 1Hz
- Dual star camera inputs





Operational Reliability, Uncompromising Accuracy

Real time products:
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- Clock bias and frequency monitoring
- GPS Integrity monitoring

Near real time products (sub-hourly to daily):
- Low Earth satellite orbits (TOPEX, Jason, GRACE)
- Sea surface height
- Earth orientation parameters

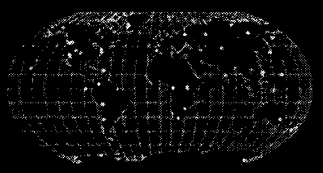
JPL IGS Analysis Center precise geodetic products:
- GPS orbits and clocks (various latencies)
- Earth orientation, site coordinates, reference frame

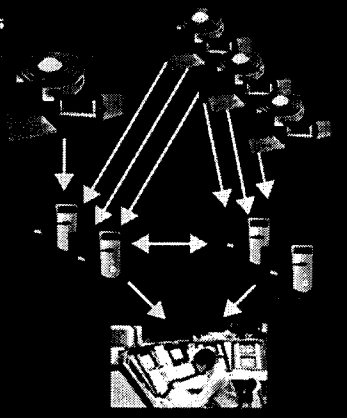
Automatic GIPSY (ag) e-mail positioning services

System engineering and analysis:
- Tracking systems design
- Simulations
- System integration and testing

9/18/02 Version
Cleared under same
CL#

Global coverage of JPL real-time sites





Robust Network Architecture

No single points of failure
- Redundant ground GPS network
- Redundant data paths
- Redundant operation centers

Dynamic network configuration
- Automatic fault detection and data rerouting

Real Time GIPSY (RTG) Orbit Determination Software

Patented state-space orbit determination approach
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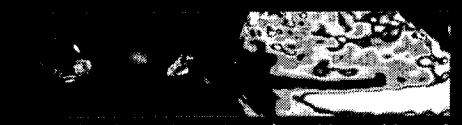


Sea surface height from TOPEX/Poseidon and Jason-1

Gravity recovery from GRACE

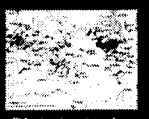
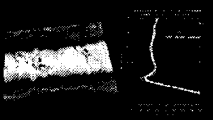


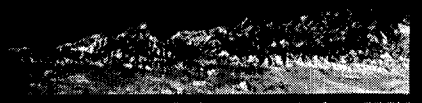
Plate tectonics

Natural hazard monitoring

Global ionospheric weather maps



Atmospheric temperature from GPS occultations



Radar topography from SRTM

International GPS Service (IGS) Central Bureau

Space Systems and Applications

Real Time Systems

Products

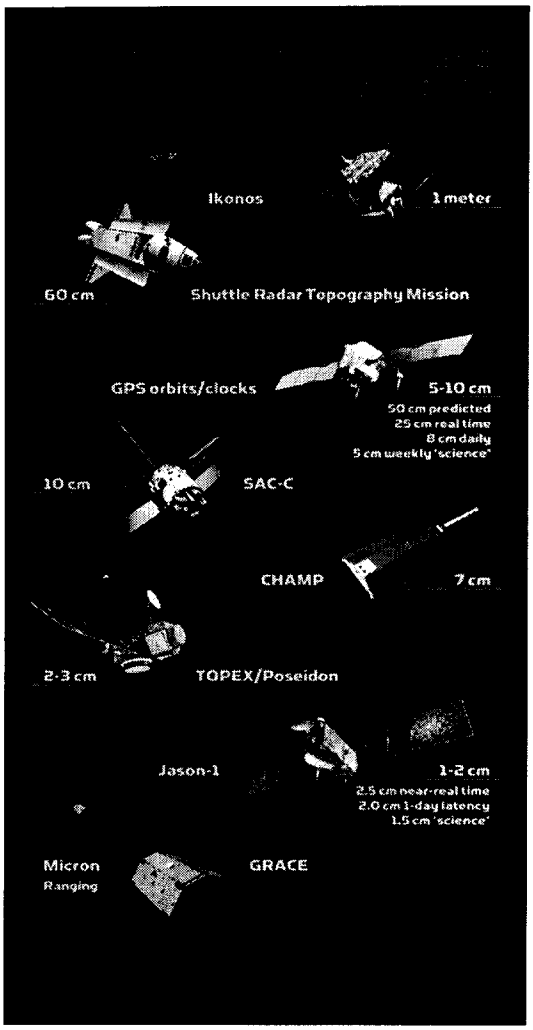
Jet Propulsion Laboratory
California Institute of Technology

Engineering Trailblazing for Challenging Terrestrial, Air, and Space Applications

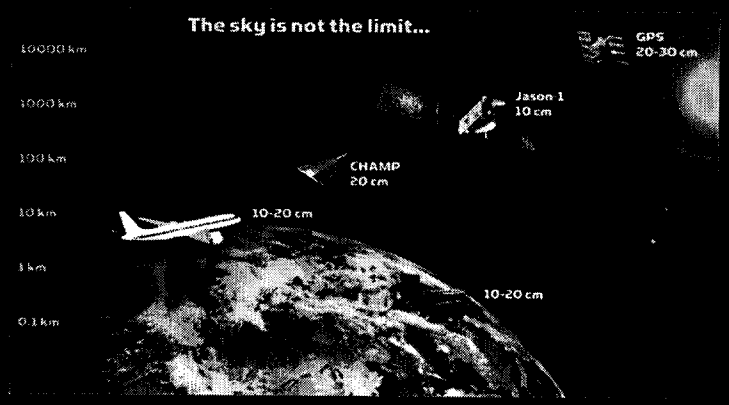
Unparalleled track record of GPS innovation and expertise:

- *ultra-precise positioning*
- *receiver technology*
- *orbit determination*
- *differential systems*
- *software systems*
- *tracking networks*
- *simulations*
- *satellite systems*
- *remote sensing*

NASA

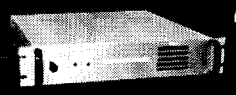

Ikonos
1 meter
60 cm
Shuttle Radar Topography Mission
GPS orbits/clocks
5-10 cm
50 cm predicted
25 cm real time
8 cm daily
5 cm weekly 'science'
10 cm
SAC-C
CHAMP
7 cm
2-3 cm
TOPEX/Poseidon
Jason-1
1-2 cm
2.5 cm near-real time
2.0 cm 1-day latency
1.5 cm 'science'
Micron
Ranging
GRACE

The sky is not the limit...

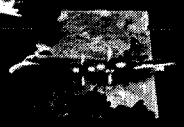


Aviation Breakthrough: Freedom from Local Infrastructure
10 cm Horizontal Accuracy; 20 cm Vertical Accuracy

- Extensive flight demonstrations
- Flexible rack-mount aviation payload
- Inmarsat or Iridium channels



NASA P-3 with Ice RADAR: North America



NASA AirSAR DC-8: Greenland

More Than Just Real-Time Positioning

- Sub-nanosecond time transfer
- GPS integrity monitoring
- Sub-centimeter tropospheric delays
- Global ionospheric weather

Performance Monitoring in the Public Domain: http://gipsy.jpl.nasa.gov/igdg

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2002: First centimeter radial accuracy for orbit determination of low Earth satellite (Jason-1)

2002: First micron-level cross link ranging in space (GRACE)

2002: Six operational GPS receivers currently in space; 30 flight years of operation without failure

Powerful Tools for GNSS Applications

Hundreds of licensees world-wide

Tracking Systems Data Processing, Analysis, and Simulations

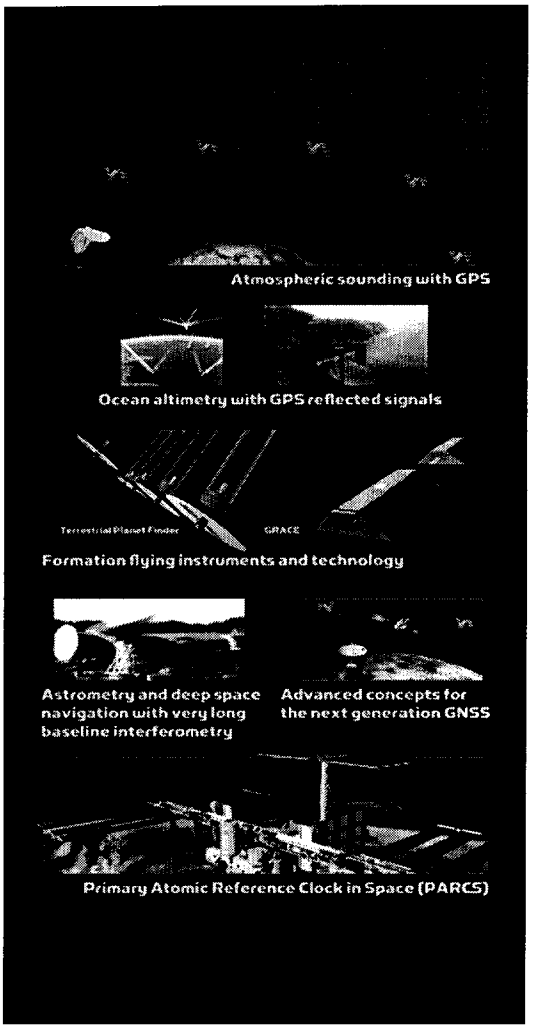
GIPSY-OASIS
- Complete models for positioning, orbit determinations, geodynamics, radio science, GPS, GNSS, SLR, DORIS, Az-El, ...

VAPORS-Visualization and Analysis Package for Orbiting Systems
- Monte Carlo simulation, visualization, and animation for communications-navigation constellations

NASA's Internet-Based Global Differential GPS (IGDG) System

RTG - Real Time GIPSY
- Operation center module for system-wide orbit determination and positioning
- Embedded user module for terrestrial, air, and space applications
- Global ionosphere maps and calibration

RTNT - Real Time Network Transfer
- Optimized data compression and communications for GPS reference site operations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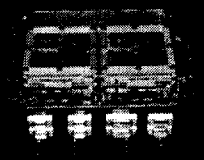

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Space Systems and Applications

Real Time Differential Systems

Products