# Laser Communications

Thoughts from

Paul Westmeyer

9 May, 2003

# NASA Mission Models REQUIREMENTS!!??

- Code M : Shuttle and Space Station
- Code Y : LEO & GEO, L1 or L2
- Code S : Mostly near Earth and the Planetary Missions
- Code U : LEO and Station

# Lessons Learned

- NASA has embarked several times on a Laser Comm Initiative and ‘failed’ on all previous attempts
  - Failed = not replaced RF baseline
- DoD has funded numerous attempts with many GRAND failures, and some cancelled projects
- ESA has made a claim of success, BUT …
  - Rate is not up to existing RF (see previous definition)
- Weather is an important variable (clouds)

# What is Different Today?

- Hard written Goals were established
  - Quais-Requirements that define what is acceptable – outdo the RF systems by at least 10X
- A Proven Team was employed (non-NASA)
- Technologies outside the nominal thinking were injected (Not-Invented-Here NIH)
  - Astronomers have been following dim lights for years
  - Successful Telecom business models were explored
    - Cell Phone towers (aka Balloons) versus LEO satellites etc…

# Very High Level Stuff

- Transformational Communications
  - Study
  - Architecture
- TDRSS Continuation
- Mars Telesat (2009)
- Jupiter Icy Moons Orbiter (2011)
- TBD Missions

# Impacts & Consequences

- Science Missions definitions
- Flight Hardware
- Flight Software
- Test Programs
- Ground Systems
- Interactions with other ‘surprises’

# Budgets & Such Things

- Congress (FY'04) submitted
- Congress (FY'03) approved

- NASA development required by Code S
  - Nobody has a mission like Code S
    - Distance
    - Radiation
    - Power available (or not)

# Other Technologies

- Launch Services
  - Balloons
  - Sub-orbital
  - Orbital
  - Recovery
- Commercial interest
  - Terrestrial & Airborne networks

# Transformational Communications Study (TCS)

- U.S. Gov't activity designed to bring the optical communications revolution into trades for future DoD and Intel functions.
  - (Space/Air/Ground/Underwater)
- Has a 'long history' ---- most classified
- Space component of Non-DoD/Intel included NASA's TDRSS

# Transformational Communications Architecture (TCA)

- Office is headed up by NRO
- Work is covered in the popular press
- Websites include a significant amount of news
  - Some references are easily found by a simple search

# NASA Communications
(current infrastructure)

- Code M: TDRSS – Space System
- Code Y: EPGN – Ground Network
- Code S: DSN – Ground Network

- None use laser communications
- Clouds make the DSN & EPGN sites unattractive for LASER Comm

# TDRSS Continuation Study

- NASA has to develop a replacement strategy for the current TDRSS
- NASA has a role in TCA
- Money and Schedules will determine the final path taken to ensure connectivity for NASA missions that rely upon a GEO-relay

# Mars Telesat (2009)

- JPL mission with essentially a ‘TDRSS-like” function for missions orbiting/on Mars
- GSFC has lead for Laser Communications portion of mission
- GSFC/JPL & MIT/Lincoln Labs have developed a strawman design & preliminary concepts

# Strawman Design

- Purpose – define a working solution as an existence proof;
  - Ground, Balloon, or Space based Receiver
- Essentials – A ‘light bucket approach’ counting every photon from the laser

- Details are being placed on a web-page
- Industry briefs were 6 May at MIT/LL

# Mars Telesat Laser Comm
## (major system design issues)

- Pointing Knowledge
- Pointing Control
- Laser Life
- Detector Technology
- Collecting aperture size/partitioning
- Clouds
- Link Budget

# Mars Telesat Status

- MIT/LL has conceptualized designs that work within  a few degrees of the sun-line
- Data rates from 0.4 A.U. (closest planetary approach) can be as high as 250Mbps
  - 5 watts laser
  - 30 centimeter transmitter aperture
  - 8 meters photon bucket on the earth

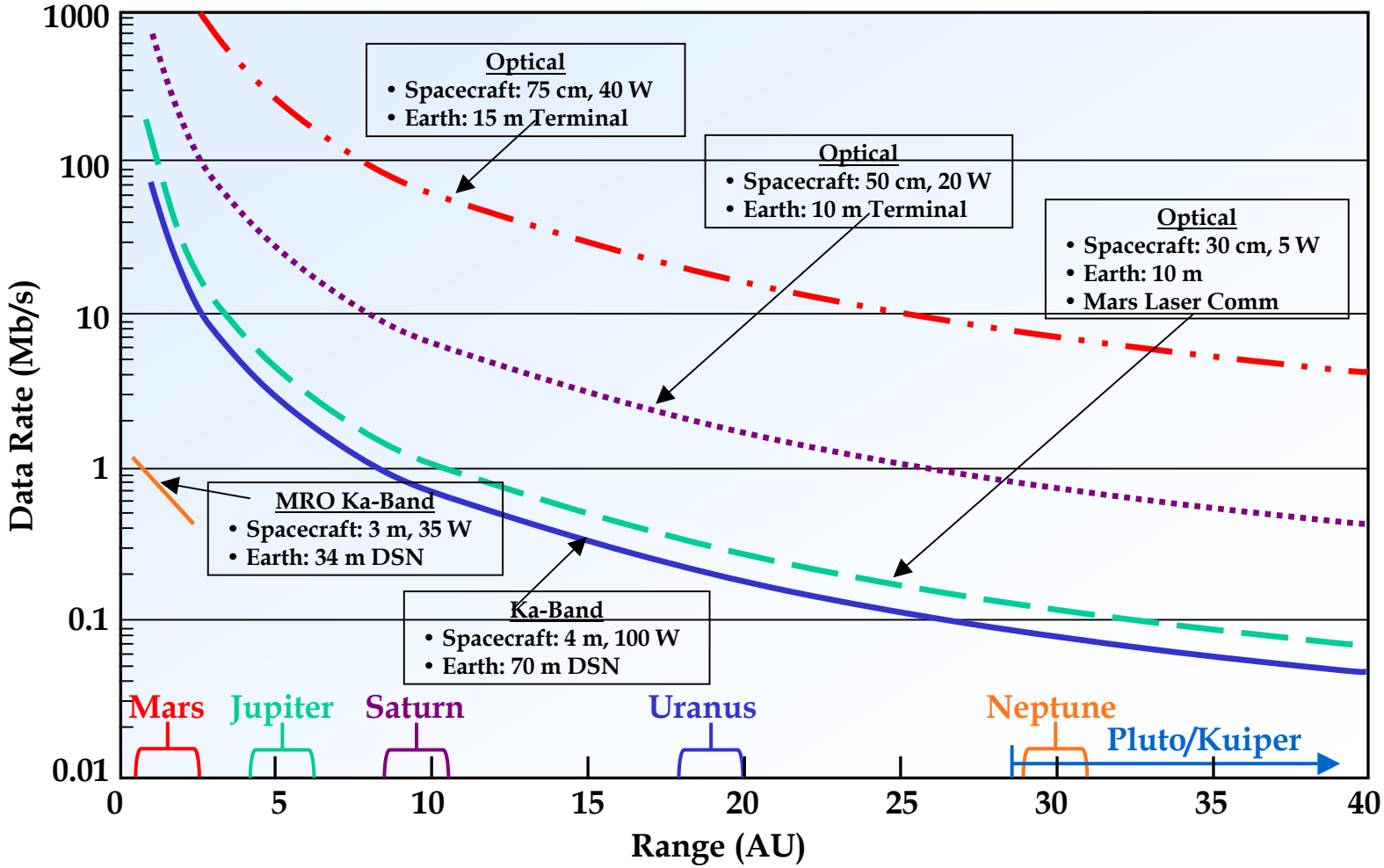
# Mars Telesat Status (cont)

- JPL has Mission Responsibility
- Optical Communications Capability is funded with $300M (FY'04 budget)
  - Flight Terminal
  - S/C I&T for terminal
  - Receiver
  - Testbeds, Engineering model etc…

# Jupiter Icy Moons Orbiter (JIMO)

- NASA's first Project Prometheus Mission
  - FY '03 Approved
- Nuclear Powered (100 Kwe)
  - Power for flight to Jupiter system
  - Power for Science while in gravity wells
- Trades started to explore Laser Communications in conjunction 'with' or 'in place' of any RF system

# The Potential of Laser Communications




Note: 70 Meter Ka-Band DSN does not yet exist

# Science Mission Definitions

- Mars can be mapped at a rate that is more than 100X any previous strategy
- Jupiter Icy Moons Orbiter is planning for more than a Mbps (maybe even 10+Mbps) science opportunities
  - EARTH-SCIENCE at the outer planets is possible!!!!

# Flight Hardware
(beyond the laser equipment)

- Beacon approach to laser communications provides a natural Forward Link (data rates can be Mbps) --- for missions outside the GEO-ring
- Laser systems (inside GEO)can provide NASA with:
  - ‘Omni-like’ laser coverage
  - Gbps on the Return
  - Mbps on the Forward links

# Beacon/Omni Consequence

(probably bi-directional at Mbps)

- Navigation functions can be accomplished in real-time and continuously
- Safety Nets (Earth-Point, Sun-Point etc) can be partitioned differently or eliminated
- Timing signals can be supplied externally
- Flight Software can be non-flight (leave it on the earth)
- If truly Bi-Directional then ‘Housekeeping Telemetry’ can be expanded and always in near real-time

# Gbps Return links (near Earth)

- If ‘continuous’
  - No Data Handling or routing except to Communications portal
  - No Scheduling (ground functions)
- If ‘non-continuous’
  - Rate buffering still required
  - Scheduling may be only defined by rate buffering not link availability

# Mbps on Forward Link

(more than the beacon service)

FILL IN THE OPTIONS – EXERCISE FOR STUDENTS

# Test Program

- Flood of Housekeeping Telemetry can be expected (try to find an engineer who doesn't want more data)
- High Fidelity 'event monitoring'
- Fewer cables --- hands off interfaces

- Additional exercise for the student

# Ground Systems
(test thru operations)

- Lots of data ---
- Different implementations for MOC and POC etc…
- Fault Recovery more ‘automatic’
  - The slightest ‘bump in the road’ is noticed
- More ‘reprogramming’ of flight assets
  - Bandwidth allows for adjustments
  - Schedule for developments will assume ‘in-flight’ adjustments

# ‘Surprise’

- Solar Sail strategies are predicting communications links that loiter over the polar regions
  - If successful this fill a gap in most LEO missions connectivity
- Terrestrial Fiber growth makes bandwidth available to more locations everyday

# Sub-Orbital

- Airline Industry looking at connecting in flight
  - May be able to connect to space assets
- True Sub-orbital flights are being planned for later this year --- what they can do is TBD
  - Deploy and recover ‘temporary’ satellites

# Balloons

- Tethered units in service for Southern Border monitoring
- NASA has Scientific Limited Life in service today
- NASA has Ultra-Long Duration Balloons being developed (100s of days at 100,000ft)
- DoD has Station-kept concepts for 1year at 70,000 ft

# Budgets

- Mars Telesat has $300M (FY'04-08)
- JIMO is not specific about the communications components
- TDRSS Continuation is not yet a dedicated line item --- being worked internally at HQ

# Summary

- Laser Comm is here, NASA transition is in-process, what will actually phase in, and when, is TBD
- Code S has made the first bold move
- Mr. O'Keefe has placed this as one of three initiatives in the Agency 2003 Strategic Plan