

Direct communication to Earth from Probes

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Science Rational for Atmospheric Probes to the Outer Planets

- Galileo Probe returned important results on the composition and characteristics of Jupiter's atmosphere.
- Galileo's "hot spot" experience demonstrated the vulnerability of probe missions. Juno mission will help prevent repeating this.
- We need to:
 - Minimize cost of entry probes.
 - Consider direct to Earth communications.
 - Determine where, how many, and how deep.
 - Science goals and objectives must consider cost and technology readiness
 - Communicate prioritization of targets.
 - Break free of the paradigm or the "old" way of doing business!

Controlling the Scientific Appetite

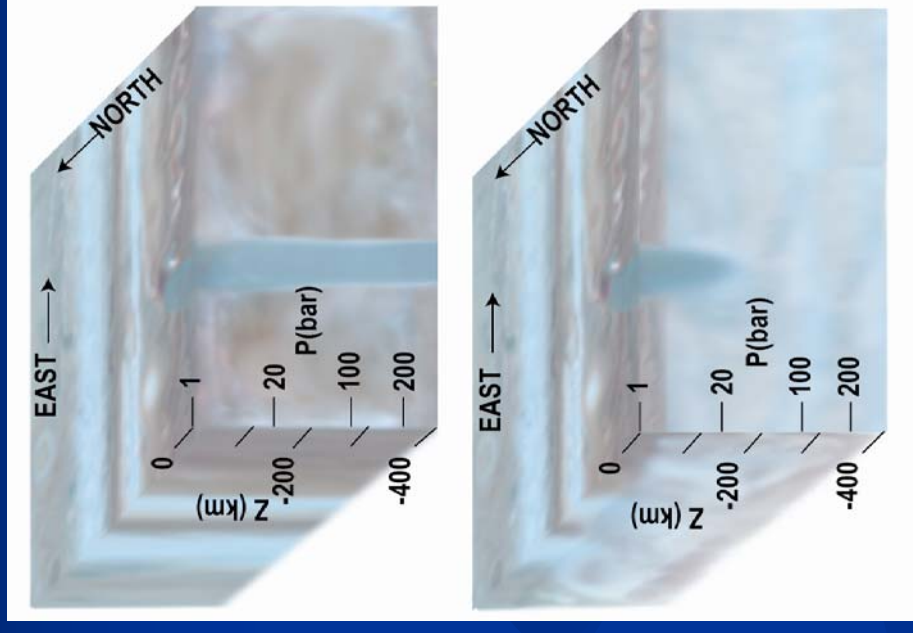
- Key to getting approved (or selected) is controlling science needs.
- Science requirements drive cost and timeframe:
 - Depth of probe required
 - Data rates
 - Heat shields.
- > 20 bars for Jupiter, but Saturn, Uranus and Neptune probes would return important results at 10-20 bars.
- Water abundance at Saturn, Uranus and Neptune requires >>100 bars and is not possible in the near future.
- Useful data rates are possible through direct communications
- Direct-communications relieves the requirement for a relay spacecraft typically many times the cost of the probe itself.

Learning more about Jupiter *before* we send more probes

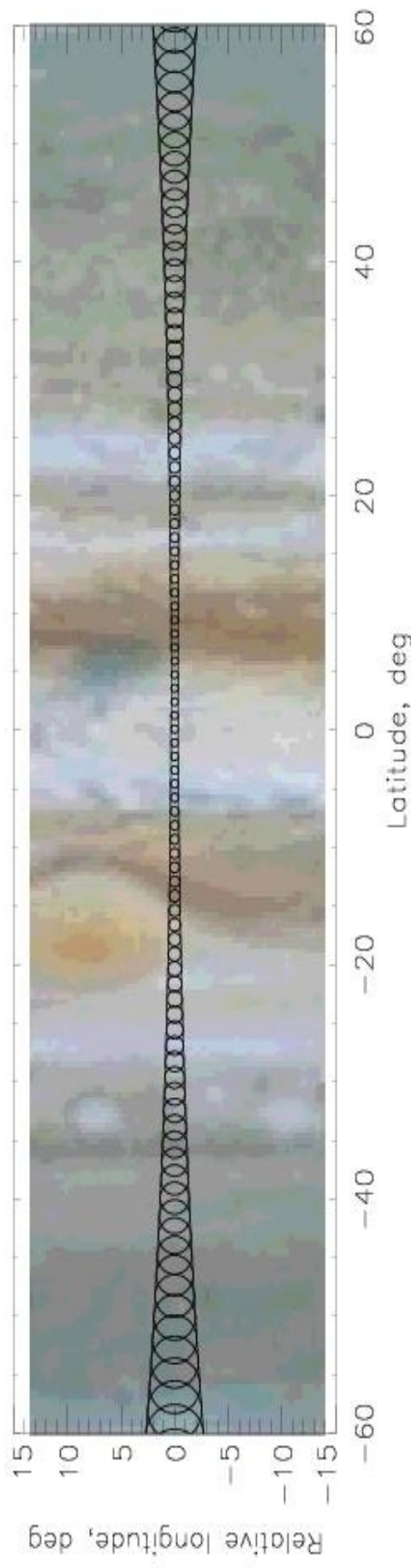
How deep does Jupiter's zone and belt structure go?

How many probes are needed? How deep? How important is latitude coverage?

Juno's microwave survey will help answer these questions for future probe missions to Jupiter and the other giant planets.



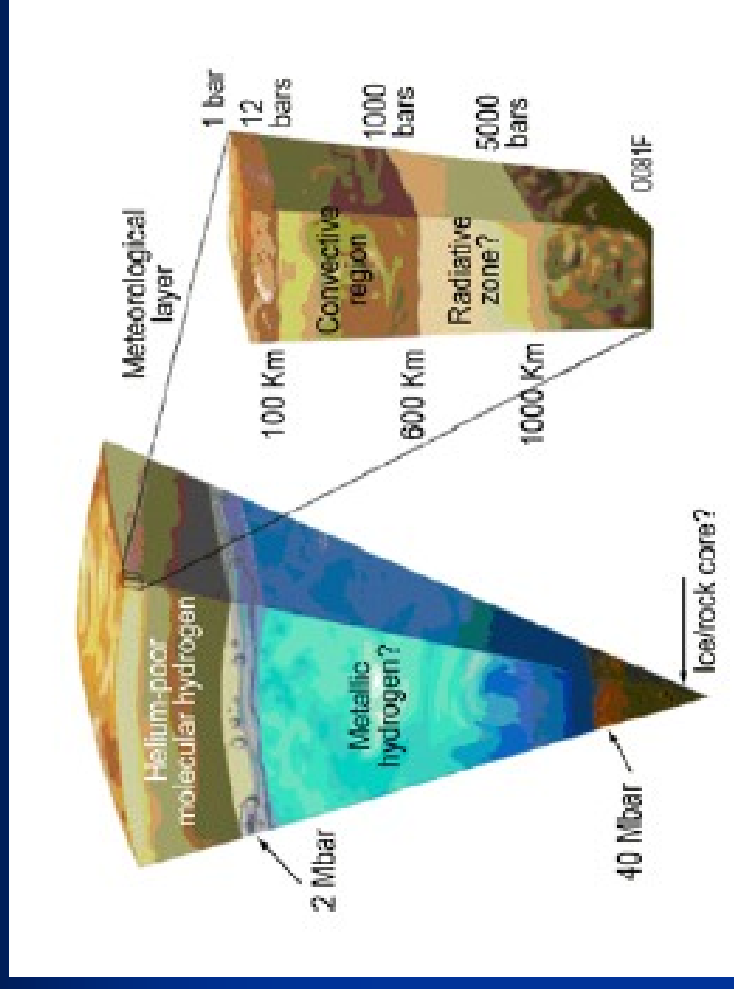
Sample Microwave Scan From Juno



Juno's microwave maps brightness temperature variations in Jupiter's atmosphere at all latitudes at multiple frequencies providing information as a function of depth to $P > 100$ bars.

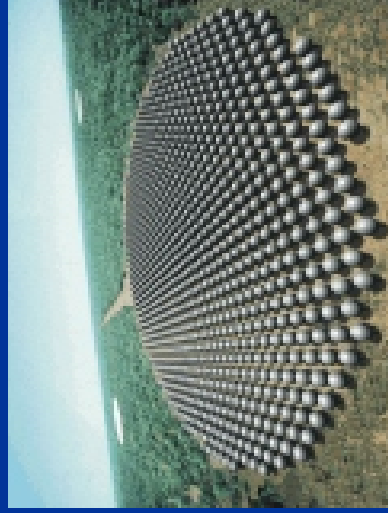
Juno will resolve the zone-belt structure and other features such as ovals, great red spot, etc.

Jupiter's Deep Interior



- Probes are an important component of understanding the deep atmospheres of Gas and Icy giant planets.
- Probes complement remote sensing techniques that provide more global coverage and/or info on deeper regions.

The Square Kilometer Array (SKA): A Breakthrough for Radio Astronomy



The SKA is an array of antennas with a collecting area of a square kilometer

- Provides 100 times the sensitivity of today's best radio telescopes
- 100+ instantaneous beams
- Global project directed by International SKA Steering Committee
- Planned completion in 2015-20
- International effort driven by Astrophysics community
- Probe community interest would be

welcome
Version 1

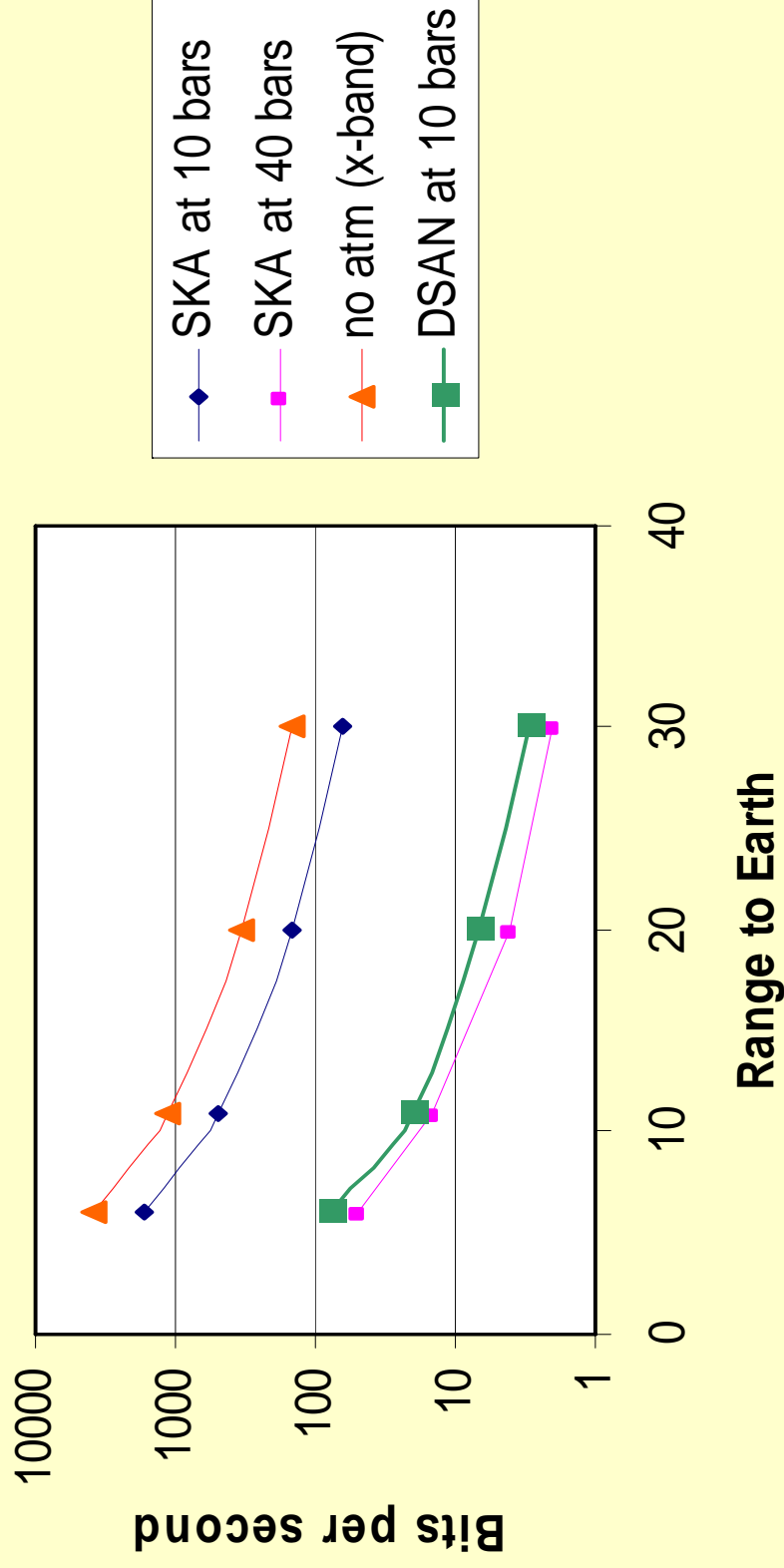
Deep Space Array-based Network (DSAN)

- 12 x 12 m antennas by 2008
- 200 x 12 m antennas in 3 primary clusters by 2012
- Secondary clusters for weather issues by 2015

Probe Direct-to-Earth Data Rate Calculations

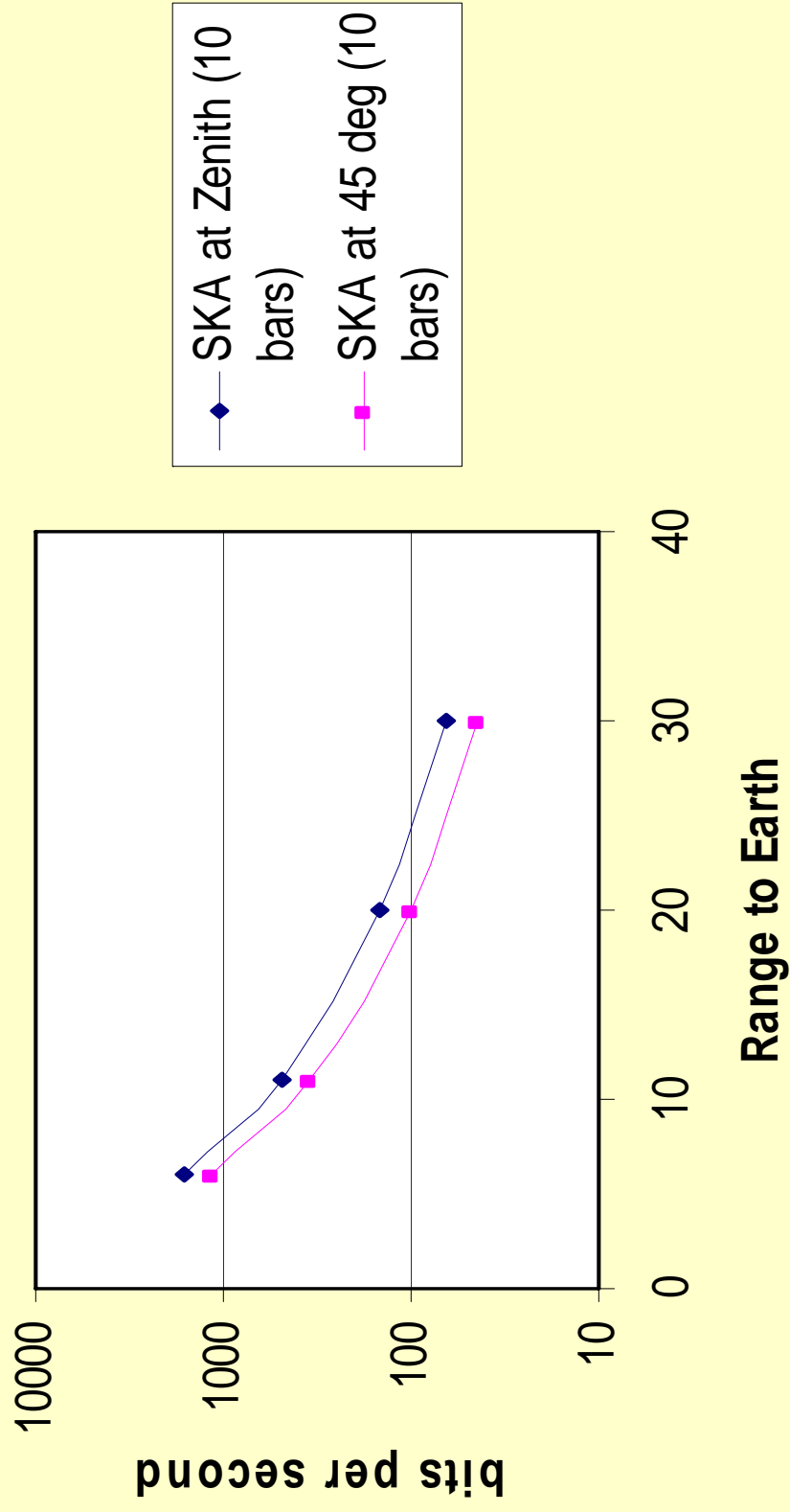
- 25 watt power (Huygens)
- Probe antenna 4 dB gain over ± 50 deg pointing (Huygens)
- L-band for outer planet entries
- X-band for satellite landers
- All calculations use Jupiter atmosphere as basis
- Data rates shown for 10 bars and 40 bars pressure
- Zenith and 45 deg slant angle (GLL was about 30 deg)
- Collecting area single dish equivalent:
 - DSAN ~ 240 m diameter (400 x 12 m, Deep Space Array-Based Network)
 - SKA ~ 1.1 km diameter (Square Kilometer Array)
- Margin: 2 dB on ground

Probe Direct to Earth Capabilities



Calculations assume attenuation by Jupiter-like atmosphere (ammonia) for all planets.

Geometry matters



Summary

- Outer planet probes will happen...when?.
- Technology (heat shield) needs to be developed.
- Cost is lower if data is direct to Earth.
- Array timeframes are consistent with plans.
- Future arrays offer lots of benefits and deserve the planetary science community support.
- Direct communications needs further study:
 - Might fit within New Frontiers cost cap.
 - Trajectory analysis and atmospheric modeling.

Enabling Ideas

- Galileo experience may drive science requirements.
- Identify science goals consistent with direct data rates.
- Separate Jupiter requirements from other giant planets.
- Don't let water drive Saturn, Uranus and Neptune.
Ask for deep probes ($\gg 100$ bars) as a second phase.
- Build on Juno mission. Complements probes & guides science and design requirements at Jupiter and beyond.
- Develop long term outer planets program incorporating Juno type missions, multi-probes and JIMO technology.