DSN Antenna Arraying; Its Past, Its Contributions to Achieving the Spitzer Space Science Mission Objectives, and Its Future Promise

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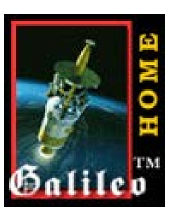

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Overview

- Introduction
  - DSN Antenna Arraying History
  - DSN Antenna Arraying Advantages
- Missions Experiences
  - Voyager's Experiences
  - Galileo's Experiences
  - Spitzer's Experiences,
  - Casini, Deep Impact, Stardust Experiences
- Future Arraying
  - Large Small Antennas Arraying Network
  - Uplink Array
- Conclusion
- Questions

History

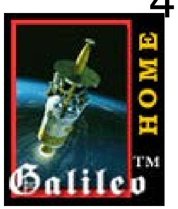
- Antenna Arraying was introduced to Deep Space Network in early 1980s
  - alternative for the over subscriptions and single point of failure of the 70-meter antenna.
    - An antenna failure in an array would only degrade the performance but not halt the service as a single 70M would.
  - accommodate the high mission data return required to adequately investigate the outer planets.
    - Antenna Arraying can exceed the effectiveness of a singular 70 meter antenna, allowing for an increased in affective aperture beyond the present 70M capability.

Arraying Advantages

- Antenna Arraying holds possibilities for better performance, increased operational robustness, and implementations cost saving
  - Antenna Arraying has wider beam-width which allows greater pointing error tolerances.
    - allows for an increase in effective aperture beyond the present 70M capability
  - DSN system operability can be increased with a multiple aperture configuration
    - Malfunction in an array would only degrade the performance but not halt the service.
    - Maintenance flexibility which allows for little to zero downtime.
  - Smaller antennas are cheaper to build than larger ones.
    - Process for building multiple smaller antennas can be automated to reduce cost

Voyager's Experiences

- Voyager has been using arraying service since the early 1980s
  - Currently DSN is still supporting VGR array passes twice a year
- Voyager required large numbers of images to perform global atmospheric fluid dynamics studies of Jupiter, Saturn, Uranus, Neptune, and Pluto
  - Arraying optimized the speed for real-time image returns
  - Large volume and image frequency exceeded anything that could be recorded on the digital tape recorder (DGT) for played back
- Earth's distances from Jupiter multiplied drastically as VGR move to Saturn, then Uranus, and Neptune
  - Arraying enabled real-time return of edited images as frequent as every 4.8 minutes



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Galileo's Experiences

- Galileo planned to use its High-Gain Antenna (HGA) to enable high rates of science data return from Jupiter
  - Galileo's HGA failed to deploy during its cruise phase
  - Low-Gain Antenna (LGA) can support at 10-20 bps vs 134 Kbps
- Galileo changed its mission plan of using 8.4-GHz X-Band to 2.3-GHz S-Band
  - DSN enhanced its three Deep Space Communication Complexes (DSCCs) to add new telemetry subsystem to handle Galileo's low-signal conditions called DSCC Galileo Telemetry
  - Enhancements were made to the Block V Receiver (BVR) and Telemetry Channel Assembly (TCA) to provide Doppler and spacecraft emergency support

Galileo's Experiences (cont.)

DSN Antenna Array

- Canberra Deep Space Communication Complex (CDSCC) performed arraying techniques to enhance Galileo's downlink signal
  - Intercontinental arraying of Goldstone 70M and Canberra 70M
  - Added two 34M to existing array of two intercontinental 70M
  - Added a 64-meter radio telescope at Parkes to existing array
  - This resulted an increased by a factor of ten to the data return of Galileo S-Band mission.

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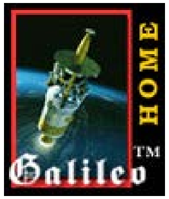
Spitzer's Experiences

- Spitzer Space Telescope launched in 2003 and expected high science data return rate with desired 2.2 Mbps for downlink rate
  - Starting October 2005, single 34M can no longer support 2.2 Mbps, leaving to only 70M for downlink support
  - In 2006, DSN expected high contentions for 70M supports from Mars and other critical missions
  - Madrid Deep Space Communication Complex (MDSCC) 70M was planned for antenna hardware maintenance up to 3 months period
- Spitzer's key operational objective is maximizing its science viewing efficiency due to its limited lifetime
  - Since launched, Spitzer has maintained a 90% science viewing efficiency
  - Spitzer's downlink passes play very critical roles to maximize its science viewing times which is to have shorter downlink passes.



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Spitzer's Experiences (cont.)

- Spitzer requested for a study by the DSN to analyze the ability to provide 70M support for the mission in 2006
  - DSN concluded the study with recommendations for Spitzer to receive DSN arraying supports
  - Arraying supports of multiple 34Ms can easily be accomplished with no conflicts for Spitzer's minimal requirements and moderate viewperiod
- Spitzer is required to modify its operational process and ground software to support DSN antenna arraying
  - Changes needed in sequence generation (SEQGEN) adaptation tools/software
    - Read updated DSN schedules with additional arraying keywords
    - Generate array compliant DSN keyword file (DKF) for DSN arraying supports

Spitzer's Experiences (cont.)

- Spitzer is required to modify its operational process and ground software to support DSN antenna arraying
  - Changes needed in multi-mission sequence generation (SEQGEN) adaptation tools/software
    - Read updated DSN schedules with additional arraying keywords
    - Generate array compliant DSN keyword file (DKF) for DSN arraying supports
  - Changed the processing procedures of the Spitzer Science Center (SSC), Mission Sequencing Team (MST), and Flight Control Team (FCT)
    - New schedule format, new DKF format, new uplink processes
  - By end of 2005, Spitzer was ready to support 2, 3, and 4 stations arraying

Spitzer's Experiences (cont.)

- Spitzer was named the most productive NASA mission in 2007 Science News metric
  - Quarterly reviews in 2006 and 2007 reported Spitzer with above 90% science efficiency
  - Spitzer warm mission will required the use of arraying to receive higher data rate and/or at lower elevation angles
  - Spitzer is looking forward to continue receive support from arraying to maximize its science efficiency.
- Spitzer has experienced and overcome all of the 70M downtimes due to maintenance, hardware failures, and other mission contentions period
  - Possible lower data rate to 1.65 Mbps or 1.1 Mbps with arraying versus 550 Kbps with a single 34M

Other Missions' Experiences

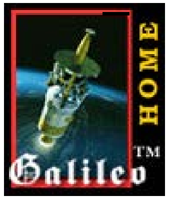
- Cassini committed to 4Gb of data per day during its orbital phase in Saturn orbit
  - –Arraying of a 70M and 34M to produce sufficient margin required
  - –Increased the data return by 25 percent in comparison to a single 70M
- Stardust's encounter with Wild 2 comet avoided data lost from single-event risks
  - –Arraying of two 34M to cut transmission time in half
- Deep Impact's single event observation of the impactor released into the asteroid was speedily received
  - –Assured data playback or the highest-valued arrived in a short amount of time to avoid data loss due to possible mishap

Future Arraying

- Smaller antennas array network
  - Arraying of small 6-12 meters antennas to achieve large aperture
  - Using automation to support monitor & control operations
  - Help fulfill high reliability, reduced cost, and high level of adaptability to evolving mission needs.

- Uplink Arraying
  - Arraying 2 identical uplink antennas can resulted four times the power of a single antennas.
  - Current technology still have some problems needed to be resolved.
    1) How to calibrate phase N numbers of uplinks in the far field using a target with short round trip light time
    2) How to repoint the uplinks at the desired target S/C without losing the calibration
    3) How to maintain stable phase for an 8 hours tracks

  DSN has experiments with bouncing two uplinks off the Moon and receiving the reflection back at a station



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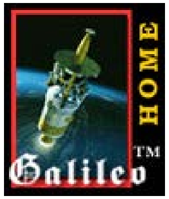
DSN Antenna Array

Conclusions

- Antenna Arraying has successfully support DSN communication & tracking operations for decades
  - Missions with arraying supports: Voyagers, Galileo, Cassini, Stardust, Deep Impact, Spitzer
  - All have successfully used antenna arraying for different purposes
  - Missions have demonstrated that arraying is indeed needed

- Antenna arraying will be an increasingly integral strategy for supporting NASA's future missions
  - Future mission requirements will demand additional innovation in the DSN.



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- QUESTIONS ?