Corona II: Returning Large Amounts of Data to Earth

Frank Crary
University of Colorado
Laboratory for Atmospheric and Space Physics
Overview

• Downlinking data over planetary distances is hard
  • Range to Earth
  • Range to Sun (Power)
  • Deep Space Network (or other antenna) time
  • Example of a CubeSat asteroid encounter

• Is there a more mechanical solution?
  • Example of a CubeSat asteroid encounter

• An even more mechanical solution
  • This may not be entirely serious…
MarCO and IRIS 2.1

• This presentation uses MarCO/IRIS 2.1 and as example
• Only flight-proven CubeSat deep space transponder
• Supports variable rates from 62.5 bps to 256 kbps
• 35 W input power
• 0.5 U and 1.2 kg for IRIS transponder
• 0.3 x 0.6 m antenna
• Antenna and power system to support telecom ~2 U
• 8 kbps from 0.87 AU
• What could this do on a 3 AU asteroid flyby mission?
Downlinks from 3 AU

• Solar power at 3 AU provides 44 W/m²
  • Assuming 29% efficiency for solar arrays
  • 35 W for IRIS transponder unlikely to be available
  • Even 30 W (2, 20x90 cm arrays) would be optimistic

• Power downlinks from batteries, recharge in between

• 8 hour downlinks with 35 W power requires 280 W-hrs
  • That is quite a bit for a CubeSat
  • Short downlinks make inefficient use of ground antenna time

• 6 W would support one, 8-hour track every other day

• 250 to 1000 bps at 2 to 4 AU range to Earth
  • >70 min. for a 1024x1024x16 bit image at 4:1 compression
Deep Space Network Availability

• There are only ten 34-m and three 70-m stations
• Eventually four 34-m stations per complex (12 total)
  • A spacecraft which would have used a 70-m will use arrayed 34-m’s
• These antennas have to support many missions
• A CubeSat is not going to be a very high priority
• Some missions can send back > 1 Mbps from Mars
  • 0.1% of that will seem like an efficient use of antenna time
• Planetary CubeSats may place a huge demand on DNS
  • Multiple spacecraft at Venus, Moon, Mars, asteroids, comets…
  • Expecting one to get many tracks per week is unrealistic
Data Storage

• Storing data is easier than broadcasting it
• A €40 memory stick stores 128 GB (1 Tbit)
  • Mass and volume are almost all packaging (too big to misplace)
  • Not a fair comparison since these are not flight rated, but…
• This is also more than a CubeSat asteroid mission needs
  • Cassini used 4 Gbits per satellite encounter at Saturn
  • New Horizons used 64 Gbits during the Pluto flyby
  • 250, 1024x1024x16-bit images, in five filters is 5.25 Gbits
• Data from flyby would depend on number of instruments
  • Optimal design would balance payload and telecom resources
Why not bring the data home?

• Use a 1 x 3.15 AU heliocentric orbit for the asteroid flyby
• Use very low downlink rate during encounter
  • Just enough to validate operations and data collection
  • Most data stored, downlink a few highly compressed thumbnails
    • Apoapsis rates support ~2 images per week at 4:1 compression
• 3 year orbital period, returns to Earth at perihelion
  • Not a targeted return to Earth, just getting close (e.g. < 0.1 AU)
• 35 W for transponder requires 30 x 30 cm array
  • Still want to downlink on batteries but with higher duty cycle
• 256 kbps downlink (IRIS v2.1 max) within 0.15 AU of Earth
  • One image every 17 seconds, not 70 minutes
• 60 Gbits returned with 1 downlink / 2 weeks
Would you really do it that way?

• No, not exactly; this was just an illustration
• Increases required duration of the mission
• Payload and telecommunications should be balanced
  • More instruments and smaller antenna?
• Operational issues
  • Is the aphelion downlink rate enough for operations?
  • One contact every two weeks? Is that safe?
  • How much would spacecraft autonomy affect this?
• Transponder with low power mode?
  • Encounter period with more frequent, lower rate sessions
• Any N:1 mean motion resonance would be similar
  • 2.17 AU aphelion with 2 year period, 4.04 AU and 4 years
Corona II: Taking the idea a bit further

• To return a very large data volume…
• Returning data as physical payload has been done before (Corona, 1959—1972)
• How small can you make a reentry capsule? 1U? 0.5U?
• How much mass memory would fit in it?
• Excessive for most planetary applications
• There are some terrestrial applications
  • Very high rate, short duration magnetospheric missions
Small entry vehicles

- Corona reentry capsules weren’t huge
  - 66 x 76.2 x 76.2 cm
- Small planetary entry vehicles have been considered more recently
  - Small Next-generation Atmospheric Probe (SNAP)
  - Admittedly for Uranus
  - 22.4 km/s entry speed
  - Sayanagi et al. (PSDS3 study report)
  - 30 kg, 4 kg payload

- For a 13.5 km/s entry into Earth’s atmosphere, could you make one 10x smaller?
Conclusions

• Sending data over planetary distances is difficult
• Especially for small spacecraft
• This can be solved by returning the data to Earth
  • At least for flyby missions
  • Heliocentric orbit with an Earth-resonant orbit
  • Return to the vicinity of Earth (< 0.1 AU)
  • Data rates are 1000x greater than at target
• Does require longer mission (and patients)
• For extreme applications, a reentry capsule with flash memory might even make sense