Introduction to Optical Communications for Satellites
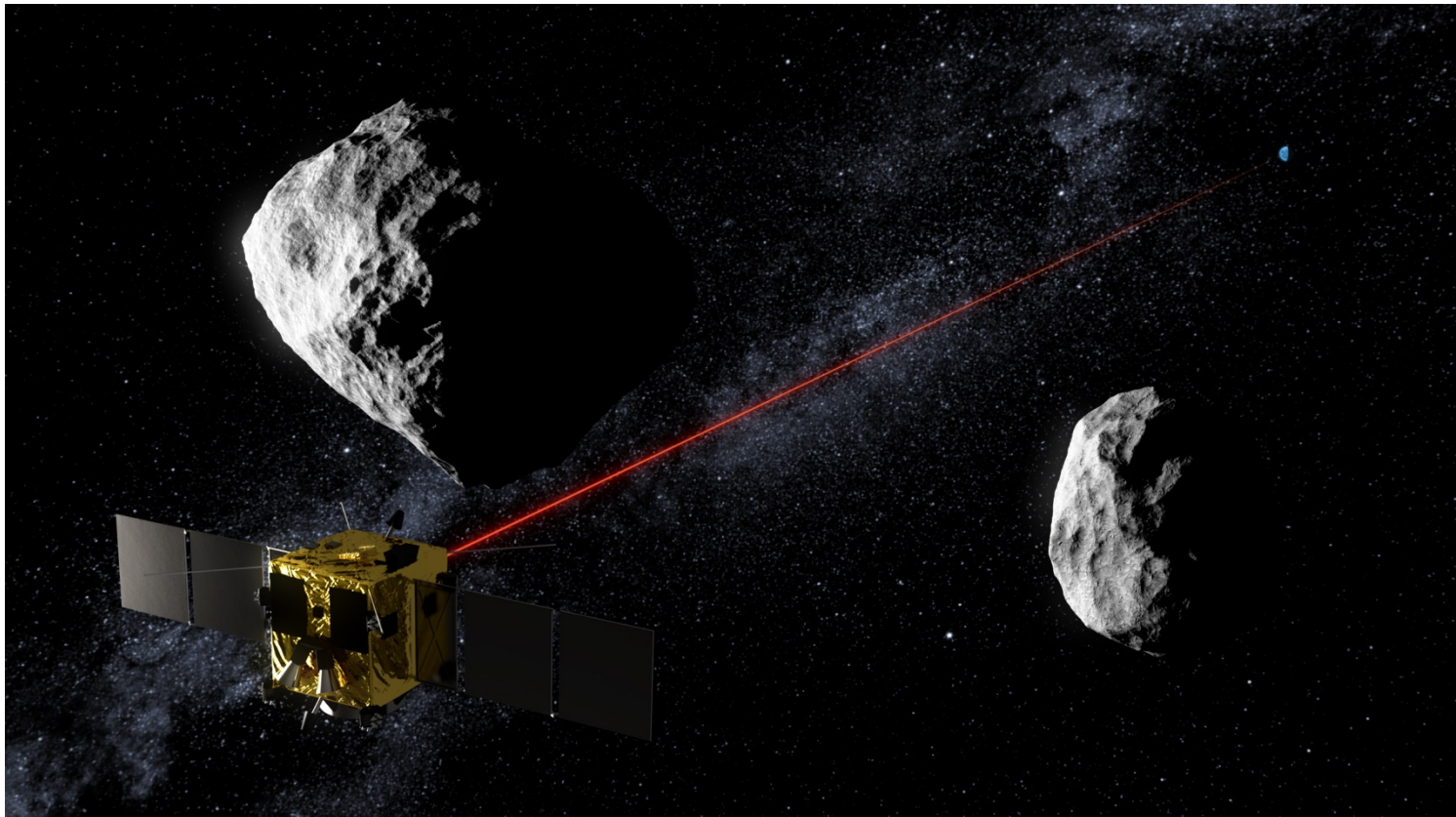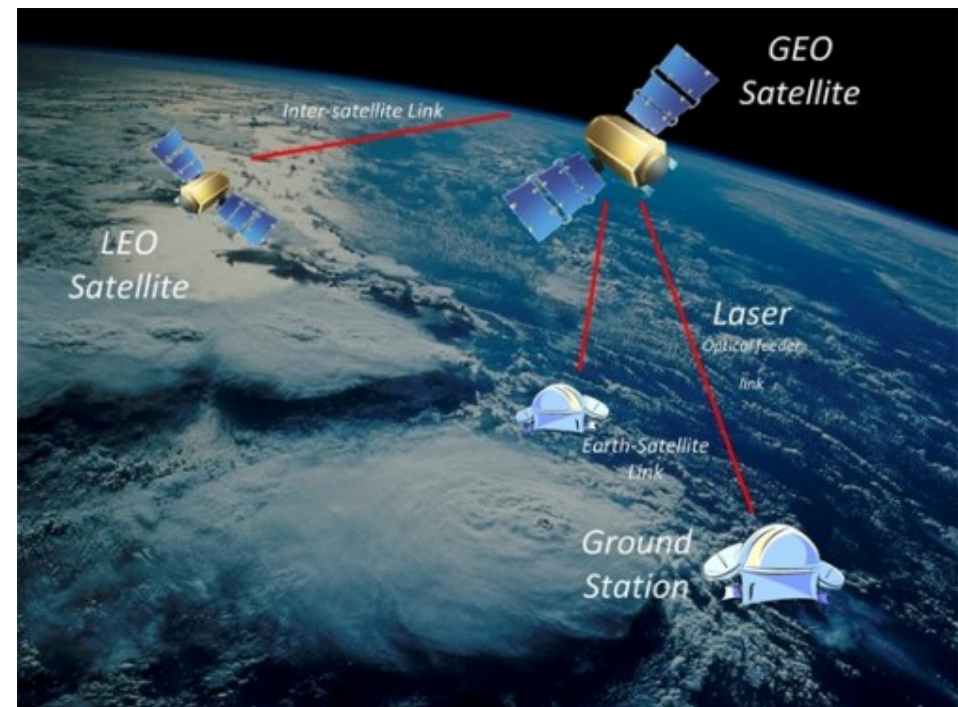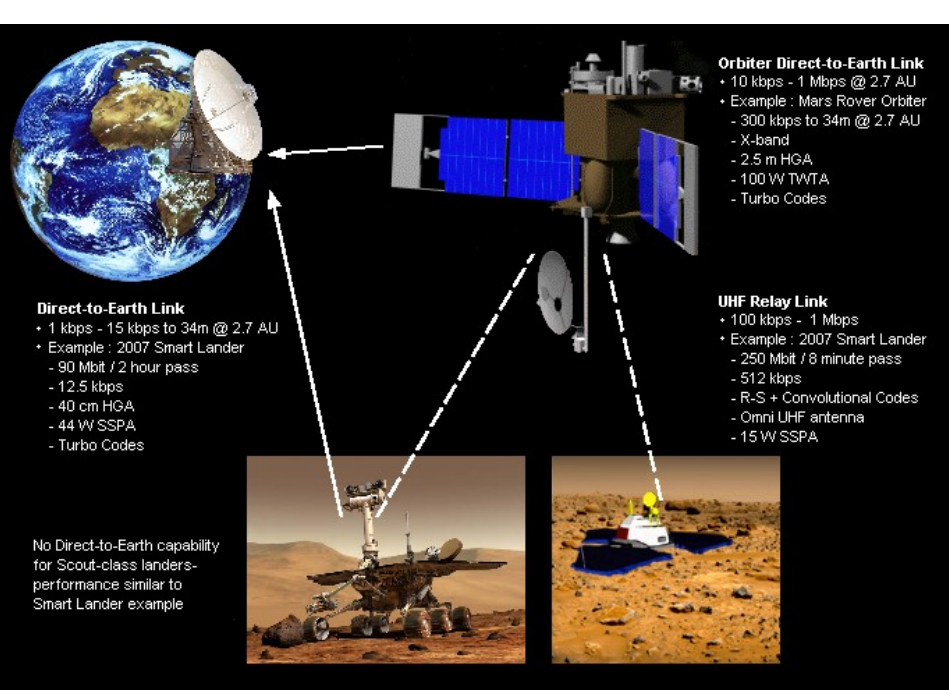
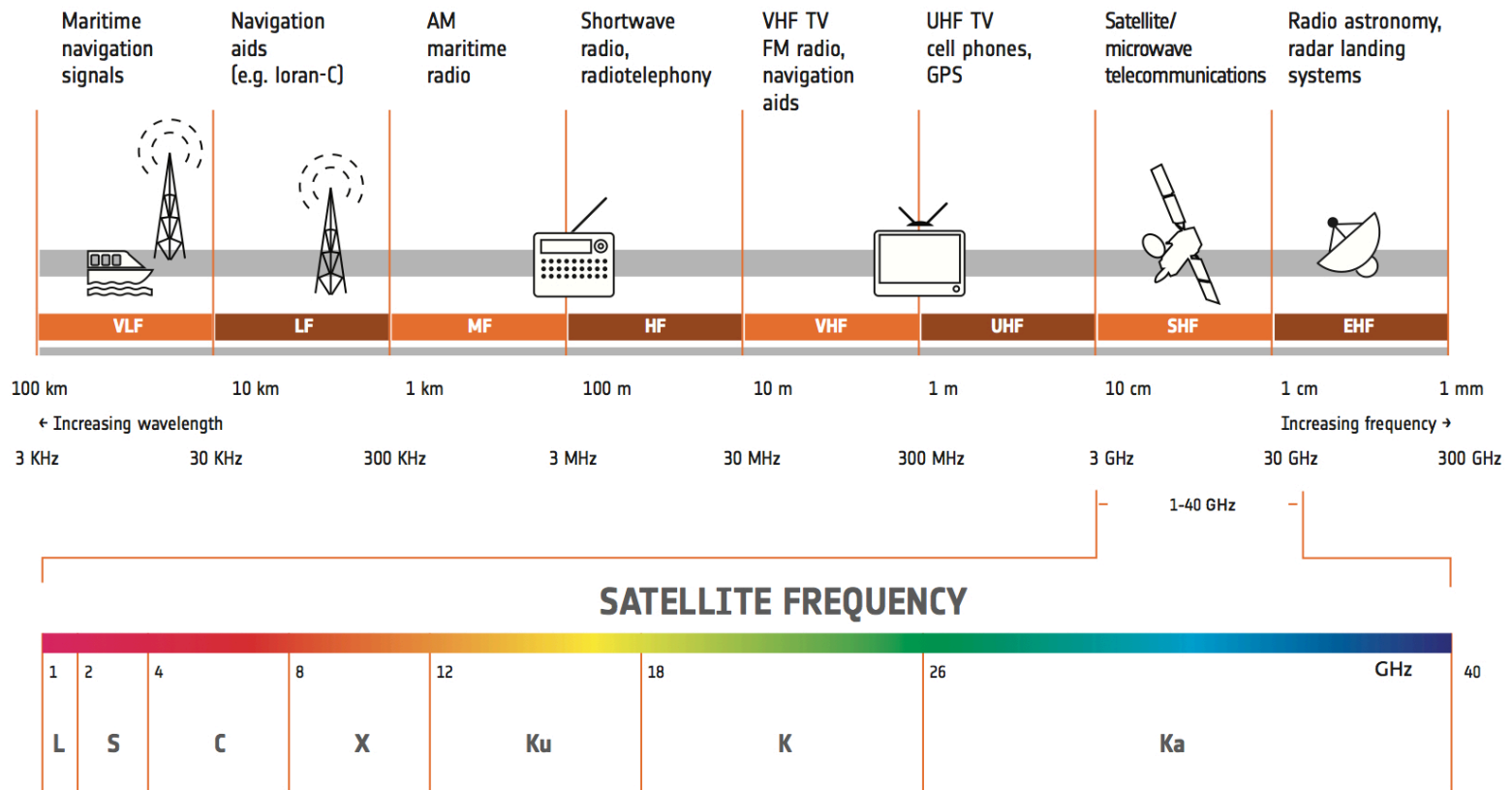Dr. Michael Küppers (ESA/ESAC)

Dr. Suzana Sburlan (JPL)

Telecommunications in space

- Uplink of commands from ground station to spacecraft
- Downlink of telemetry from spacecraft to ground
- Determination of spacecraft position and velocity
- Determination of own position (GPS or other navigation system)
- Intersatellite links

Orbiter Direct-to-Earth Link
- 10 kbps - 1 Mbps @ 2.7 AU
- Example : Mars Rover Orbiter
  - 300 kbps to 34m @ 2.7 AU
  - X-band
  - 2.5 m HGA
  - 100 W TWTA
  - Turbo Codes

Direct-to-Earth Link
- 1 kbps - 15 kbps to 34m @ 2.7 AU
- Example : 2007 Smart Lander
  - 90 Mbit / 2 hour pass
  - 12.5 kbps
  - 40 cm HGA
  - 44 W SSPA
  - Turbo Codes

UHF Relay Link
- 100 kbps - 1 Mbps
- Example : 2007 Smart Lander
  - 250 Mbit / 8 minute pass
  - 512 kbps
  - R-S + Convolutional Codes
  - Omni UHF antenna
  - 15 W SSPA

No Direct-to-Earth capability for Scout-class landers- performance similar to Smart Lander example

Source: Astrosurf.com

GEO Satellite

Inter-satellite Link

LEO Satellite

Laser Optical feeder link

Earth-Satellite Link

Ground Station

Source: techbook.co.in

Frequencies for radio communications with satellites


Source: ESA

Navigation: Global Positioning System (GPS)

- Constellation of 24 satellites in medium earth orbit (17700 km)
- Accurate knowledge of their position and time continuously broadcasted
- Three satellites needed to calculate one's position (4 satellites if time is corrected)
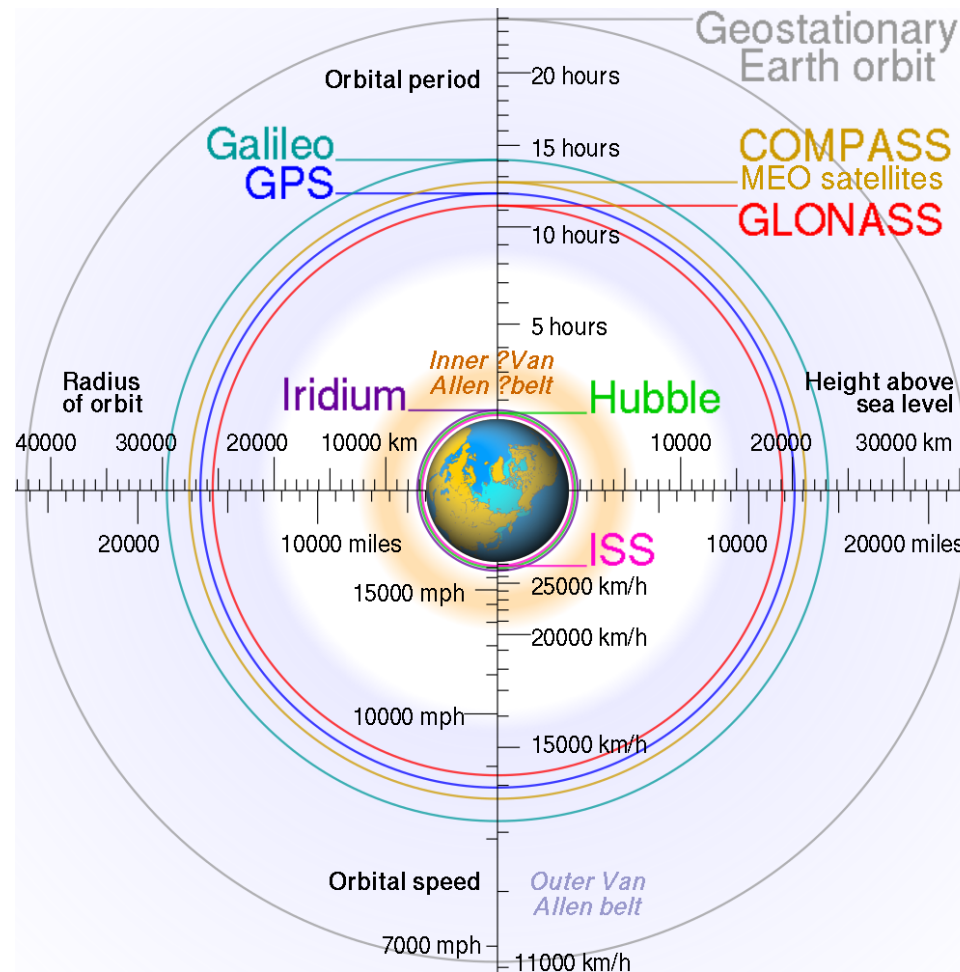
GPS example and other systems

- Example: Visibility of GPS satellites from Golden/Colorado
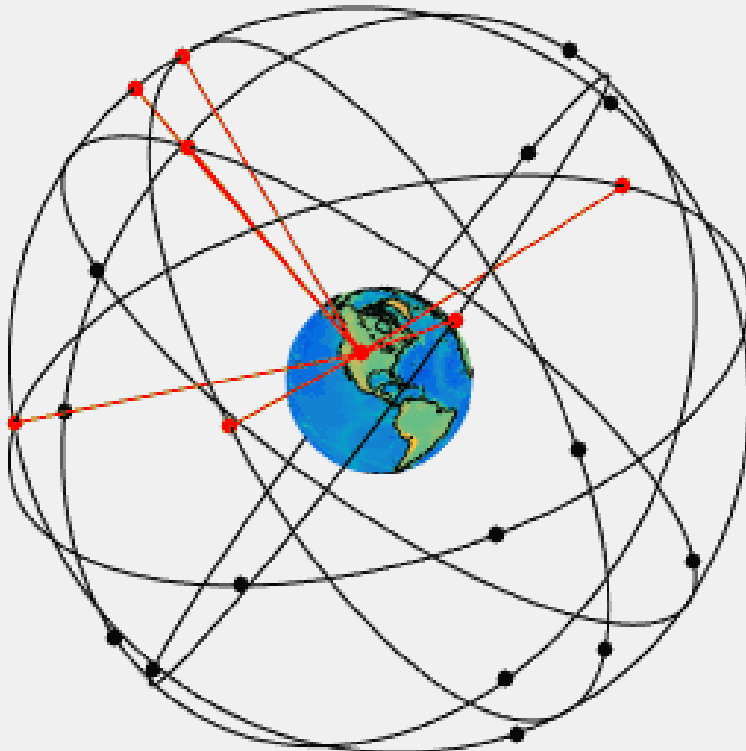

7 visible satellites

Source: Wikipedia

- Russian Glosnass system just (re)-completed
- European Galileo is being set up
  - ➢ Currently 8 satellites in orbit
  - ➢ Full capability scheduled for 2020
- Chinese, Indian, and Japanese systems are begin planned

Navigation: Position of interplanetary spacecraft

- Radial position through 2 way ranging (time of flight), radial velocity through doppler effect
  - Highly accurate
- Problem: Radio measurements are not accurate for the position perpendicular to the line of sight.
  - Example: **3 cm** wavelength (X-band), **70m** antenna (DSN)

      => diffraction limited **resolution ~1 arcmin ~65000 km** at 1 AU distance

Solution to get more accurate position measurement: delta-DOR

- Ranging of the spacecraft with two ground stations at a time
  - ❑ Now resolution limit is determined by distance between stations
- Remaining issue: Atmospheric propagation of signal will be different
  - ❑ Calibrated using nearby quasar
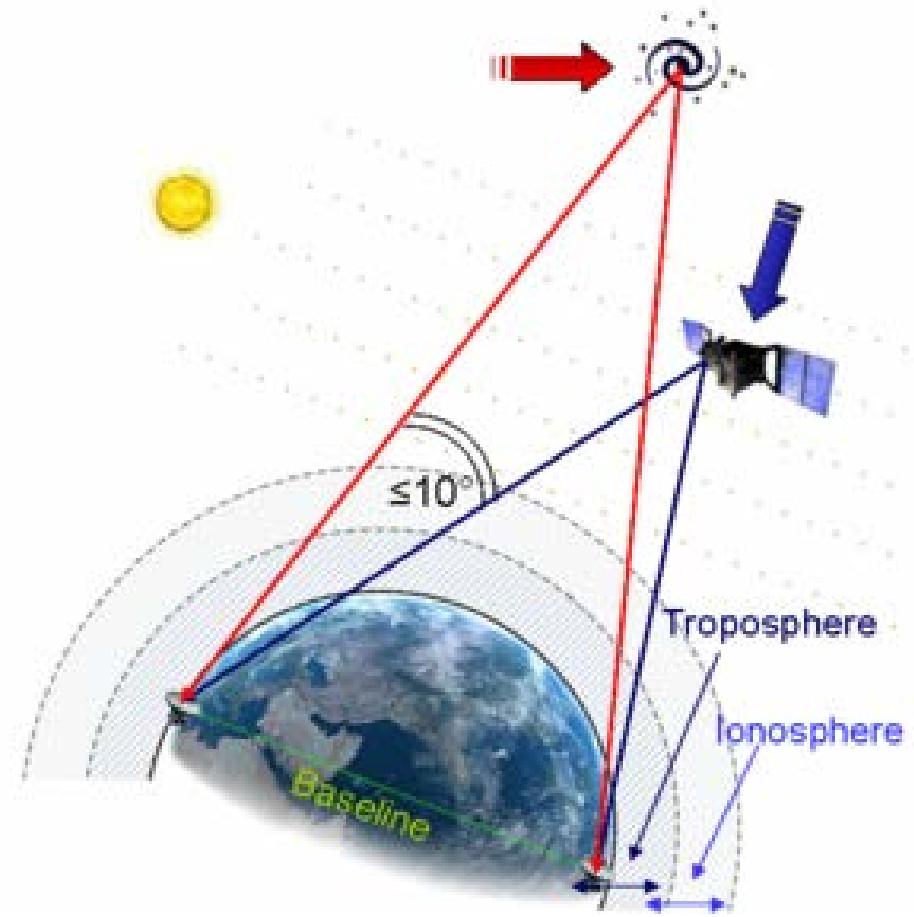
Increased data needs

- Amount of data acquired by satellites is steadily increasing

Data volume per image of different HST cameras
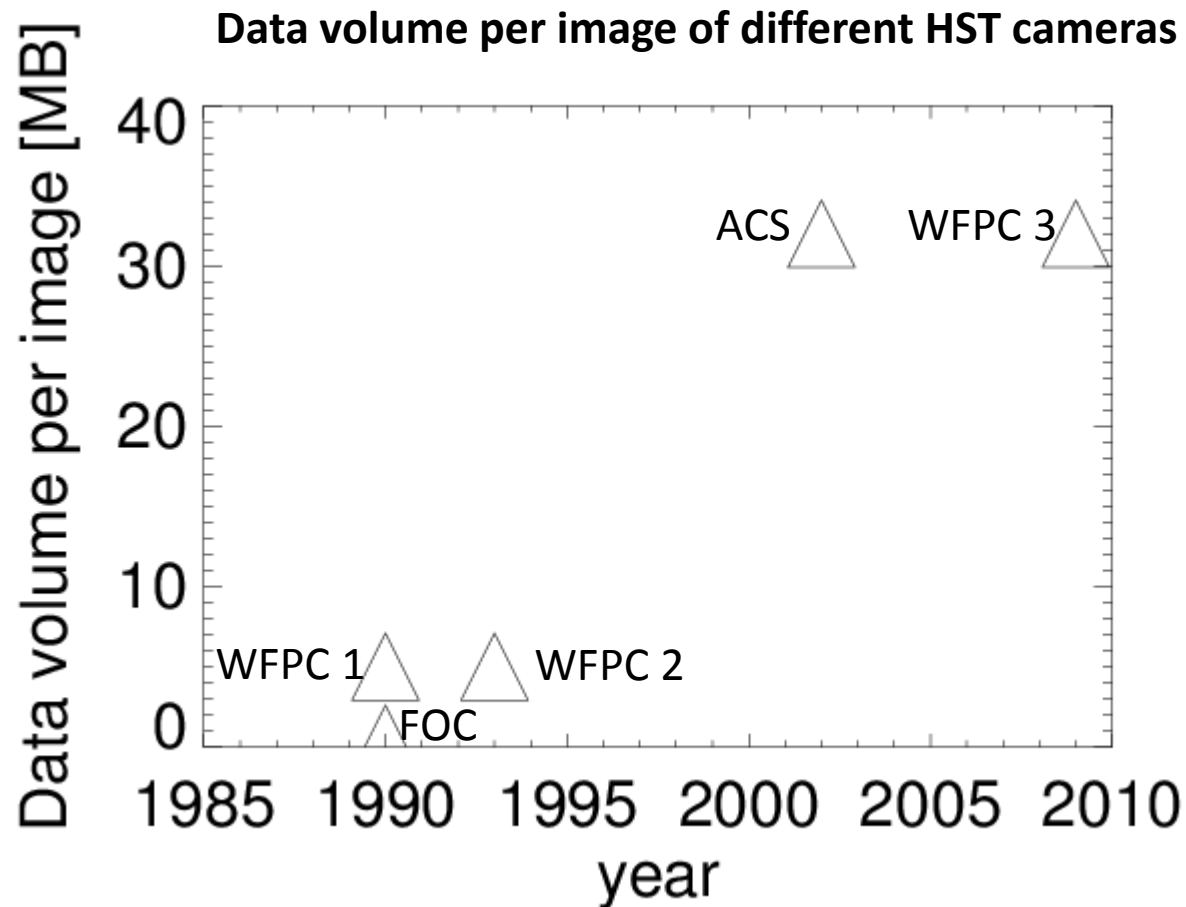
Advantages of Optical telecommunications

- Higher data rates (getting more data down)
- Better S/N ratio (if weather is good)
- More accurate navigation (with associated requirements on the pointing accuracy of the spacecraft antenna

NASA OPALS Sat.

ESA opt. ground station