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User Needs and Advances in Space Wireless Sensing & Communications

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Outline

- Introduction
  - Mission Support
  - NASA Communication Networks
- User Needs for Wireless Sensor Networks and Communications
- Advances in Communication and Navigation to Support User Needs
  - Addition of Optical Communication to the Integrated Network
  - Standardized Network Protocols
  - Adaptive, Autonomous Networking Capabilities
  - Other Advances in Communication and Navigation
- Summary and Conclusion

MISSIONS SUPPORT

98%

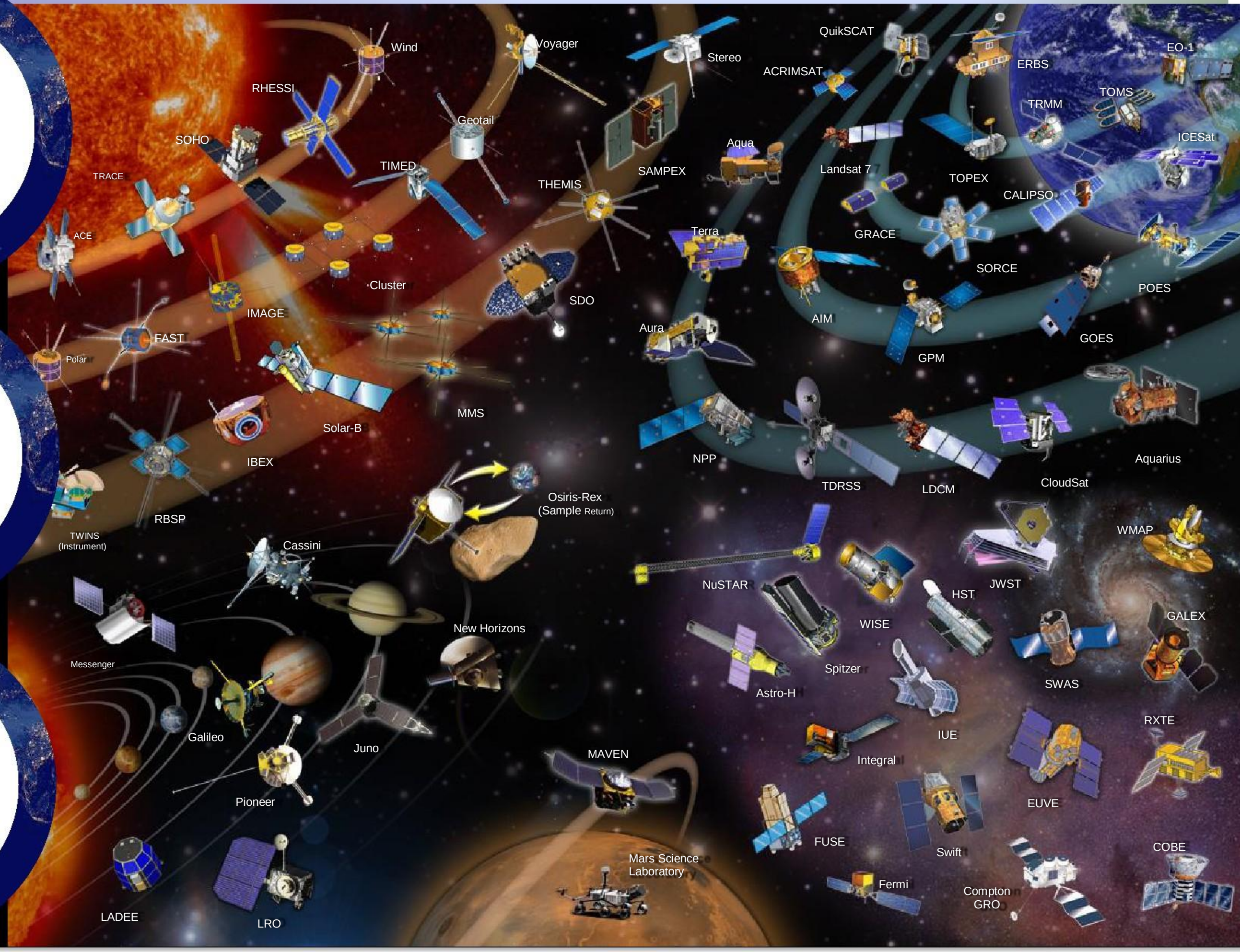
The percent of NASA communications that go through ESC each day as of July 2016

23

Average number of launches supported per year. Expected to double with increased HSF and cubesat missions

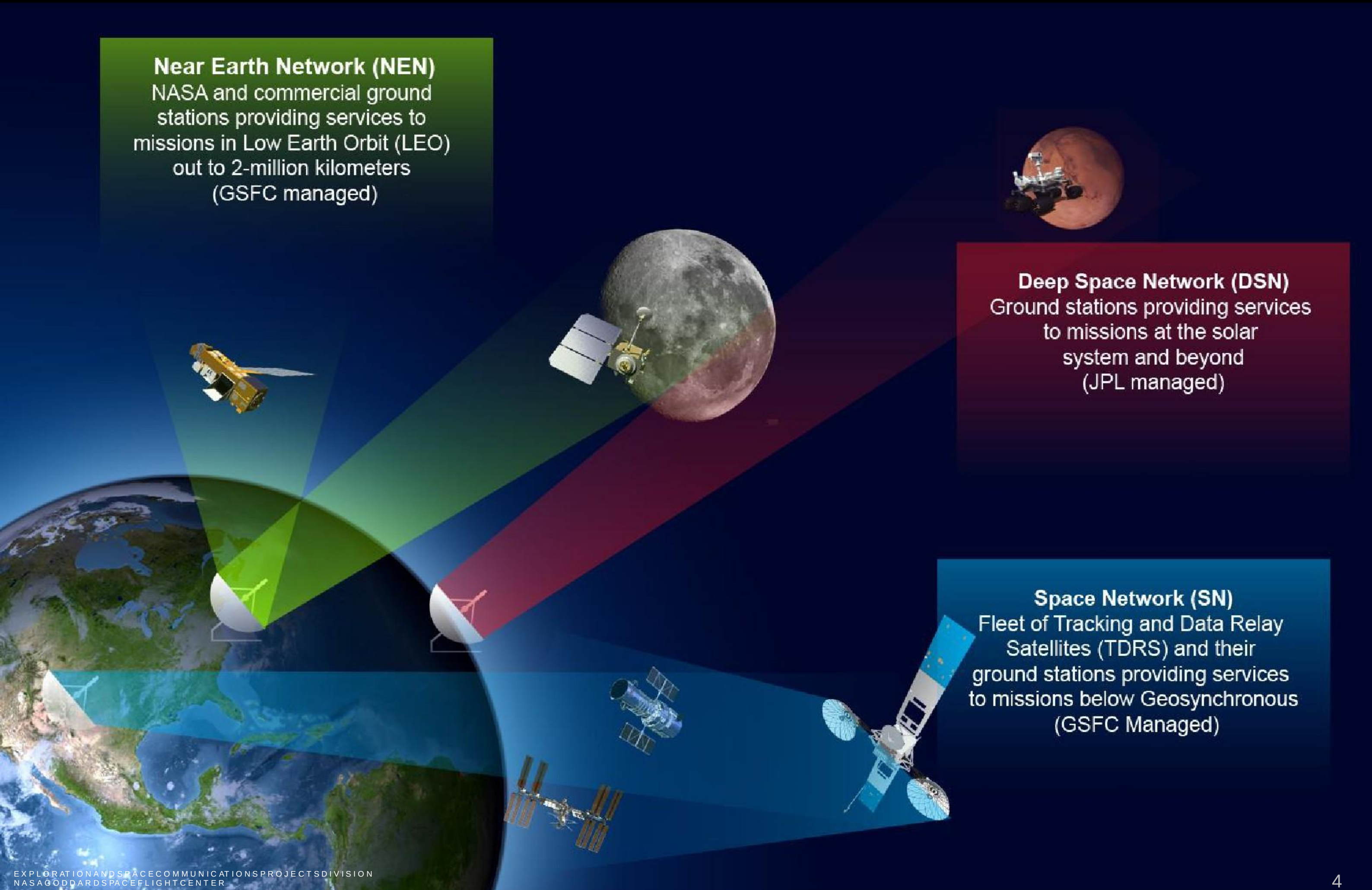
1,200

The number of Blu-ray disks worth of data SN and NEN handle every day



NASA's Space Communications Networks:

Three networks: NEN, SN, DSN



NASA Networks Span the Globe

Deep Space Network | Near Earth Network | Space Network

User Needs Scenarios - Wireless Sensor Networks for Space Exploration

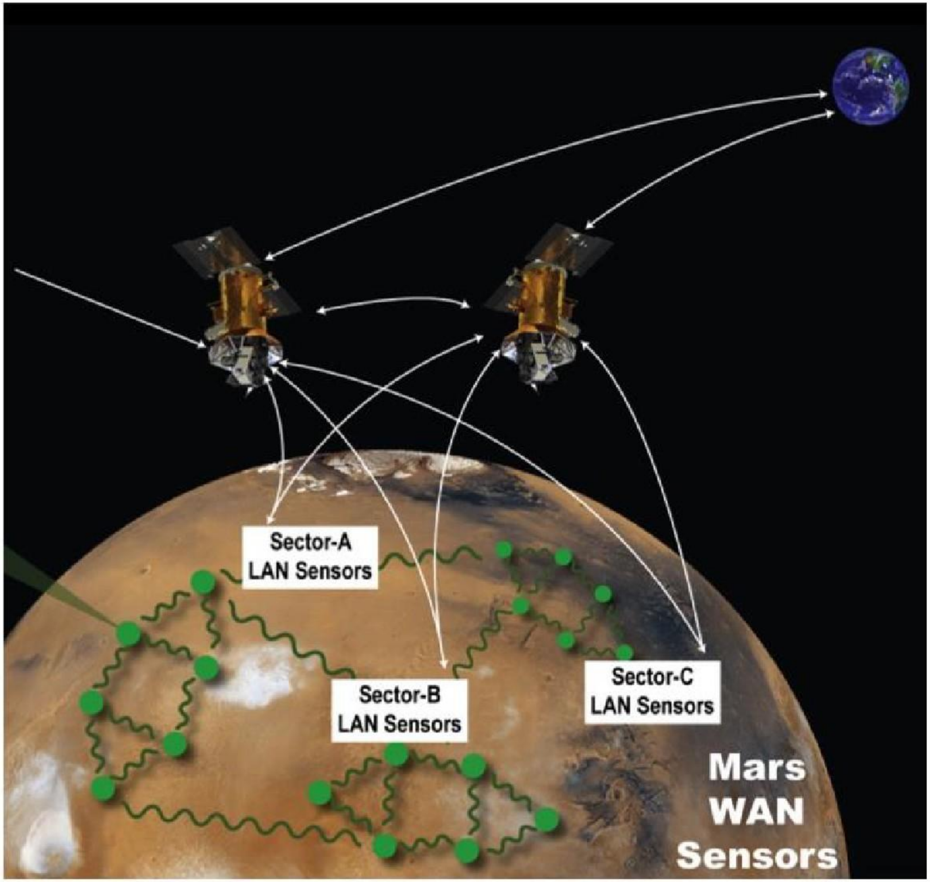
Challenges for Wireless Sensor Nodes

- How will the sensors be deployed?
- How will the sensors be powered?
- How much intelligence is implemented with the sensor nodes?
- How will they communicate – network topology, protocols, interoperability?
- Operation and control?
- Network Security?

Desired Capabilities of a Sensor Node?

- The functions in the sensor node may include:
  - Managing data collection/fusion/storage/ retrieval from the sensors/instrument
  - Autonomous networking capabilities
  - Power management functions, energy conservation
  - Co-existence and mobility management
  - Interfacing the sensor data to the physical radio/optical communication system layer
  - Managing the radio/optical network protocols
  - Managing cognitive functions of the network

User Need Example

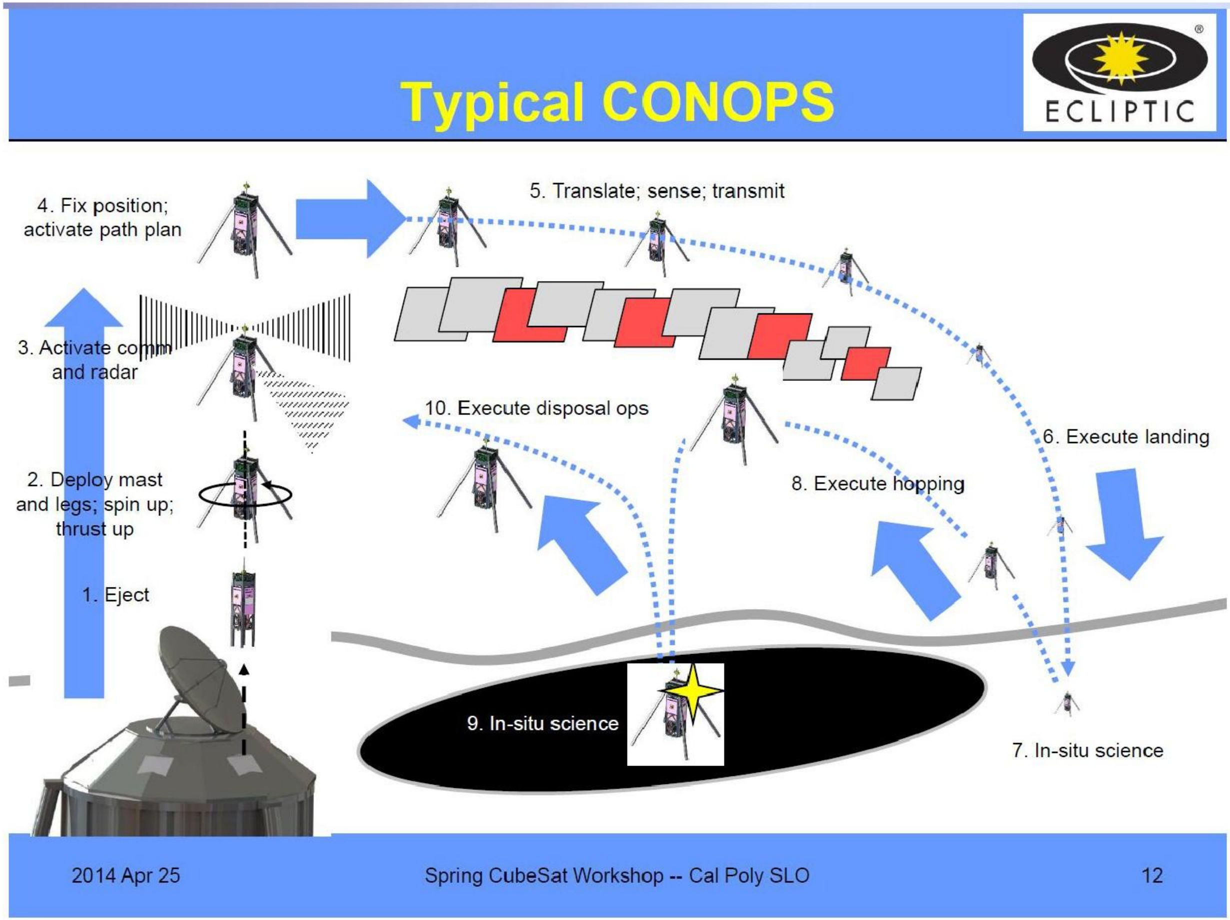


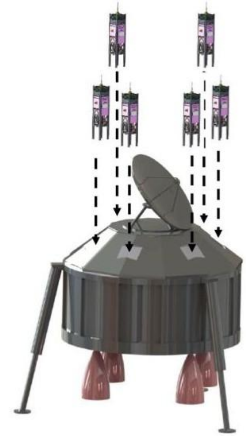
Miniature, Low-Power, Waveguide Based Infrared Fourier Transform Spectrometer for Spacecraft Remote Sensing

- Shows the Mars Sensor Web concept that integrates sensor ensembles organized as a network that is reactive and dynamically driven. The network is designed to respond in an event- or model-driven manner, or reconfigured as needed.

(Courtesy of Tilak Hewagama, et al. 2013)

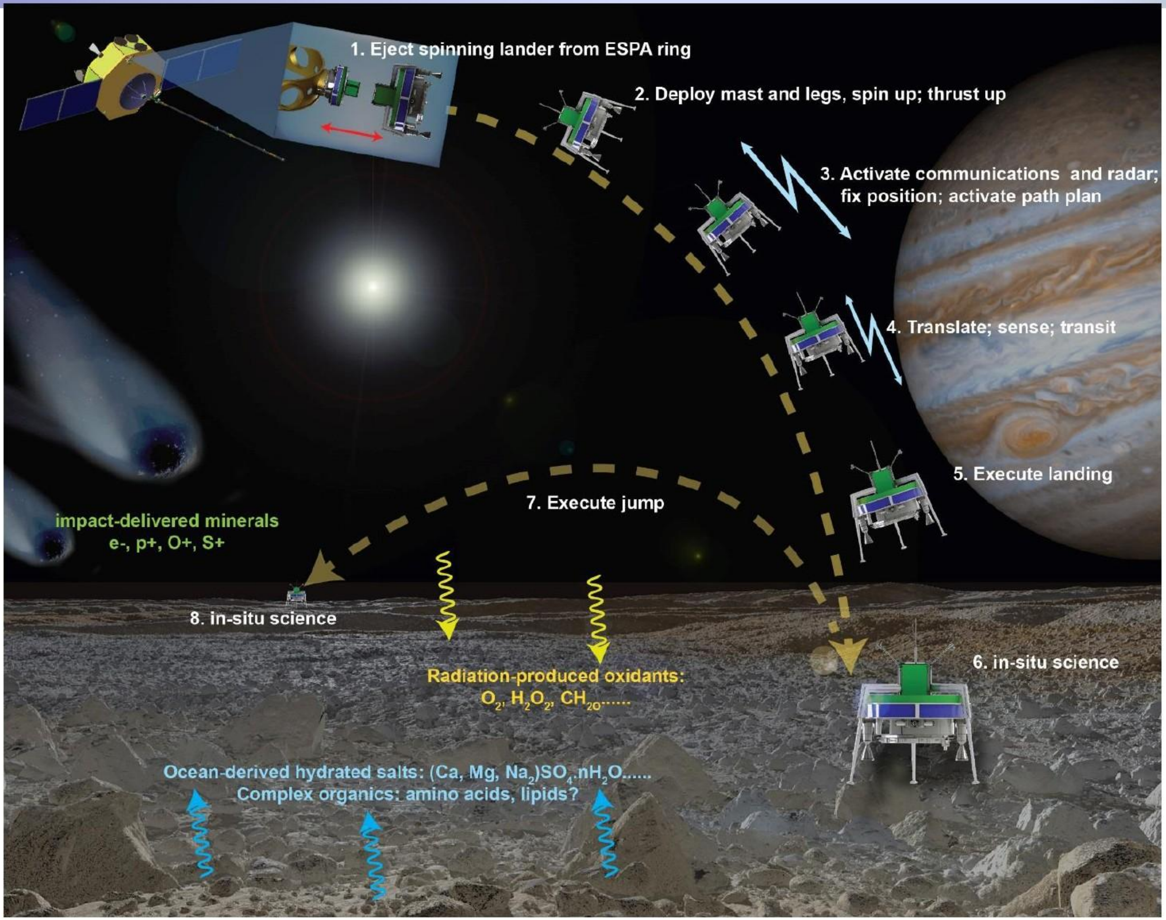
User Needs Example: CubeSat-Class Spinning Landers for Solar System Exploration Missions





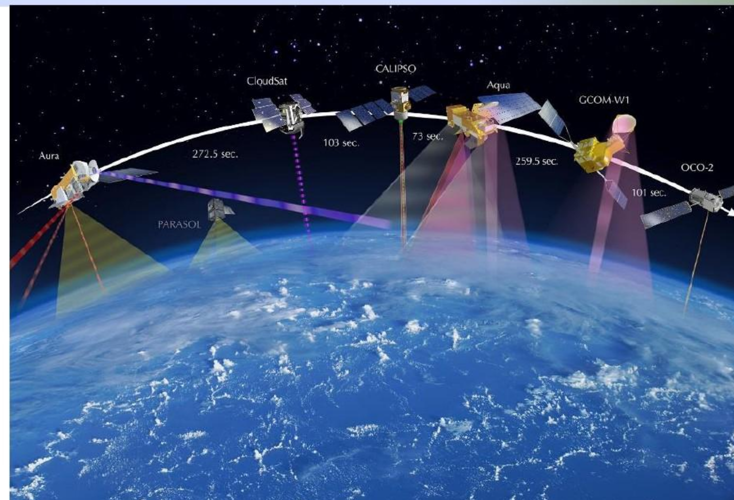
(Courtesy of Rex Ridenoure, Ecliptic Enterprises Corp.)

User Needs: SmallSat Spinning Lander with a Raman Spectrometer Payload for Future Ocean Worlds Exploration Missions

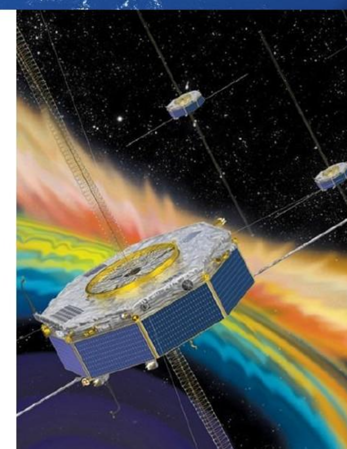


(Courtesy of R. Ridenoure et, al. 2017)

User Needs Examples

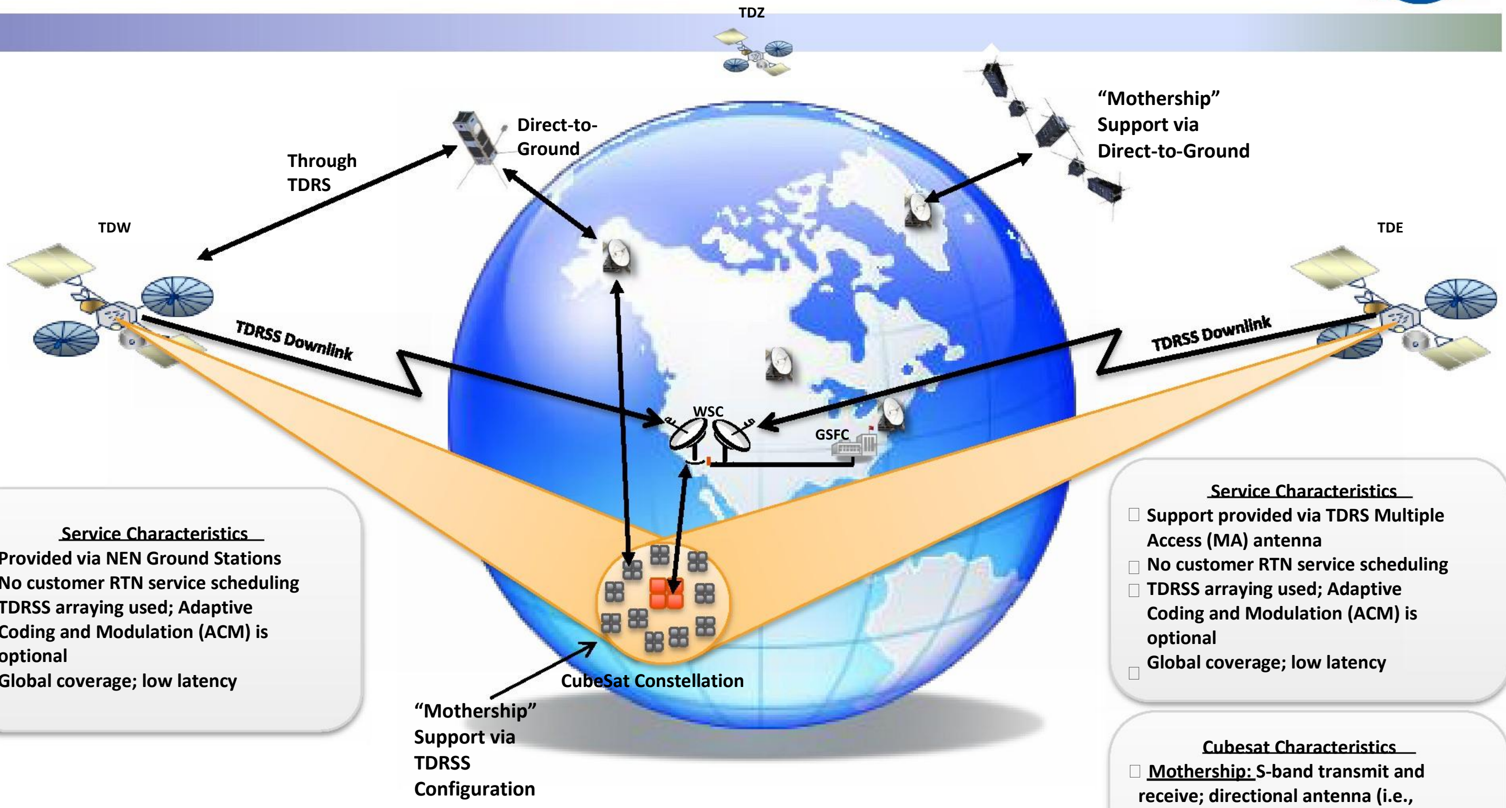


- Variable Science Data Collection
  - A mission has a lower rate of science data collection while in a nominal monitoring/baseline data collection mode
  - A science event triggers instruments to collect data at a higher rate by either turning on more instruments or increasing resolution
  - The mission is able to use UIS to acquire the necessary services to delivery all of the data even though the data volume and time of event were not predictable
- Collaborative science platforms.
  - One platform detects an event and transmits a notification to collaborating platforms, while also scheduling up the opportunity to transmit the full data collected
  - Other platforms receive the notifications, begin their appropriate response (repoint an instrument, increase resolution, etc.), and then transmit their data through the available channels
- Satellite Formation Flying
  - Small, micro, and nano satellite buses offer on opportunity to place large numbers of observation platforms into orbit
  - Small satellite maneuvering will be attained as actuator technology scales down to fit within the size, mass, and volume constraints of small satellite buses
  - Formation flying of small satellites will be achieved through the application of precision autonomous orbit determination, maneuver planning, and execution



(Coutesy of David Israel, et al. NASA GSFC)

User Needs Example: CubeSat/SmallSat Platforms



Service Characteristics

- Provided via NEN Ground Stations
- No customer RTN service scheduling
- TDRSS arraying used; Adaptive Coding and Modulation (ACM) is optional
- Global coverage; low latency

Service Characteristics

- Support provided via TDRS Multiple Access (MA) antenna
- No customer RTN service scheduling
- TDRSS arraying used; Adaptive Coding and Modulation (ACM) is optional
- Global coverage; low latency

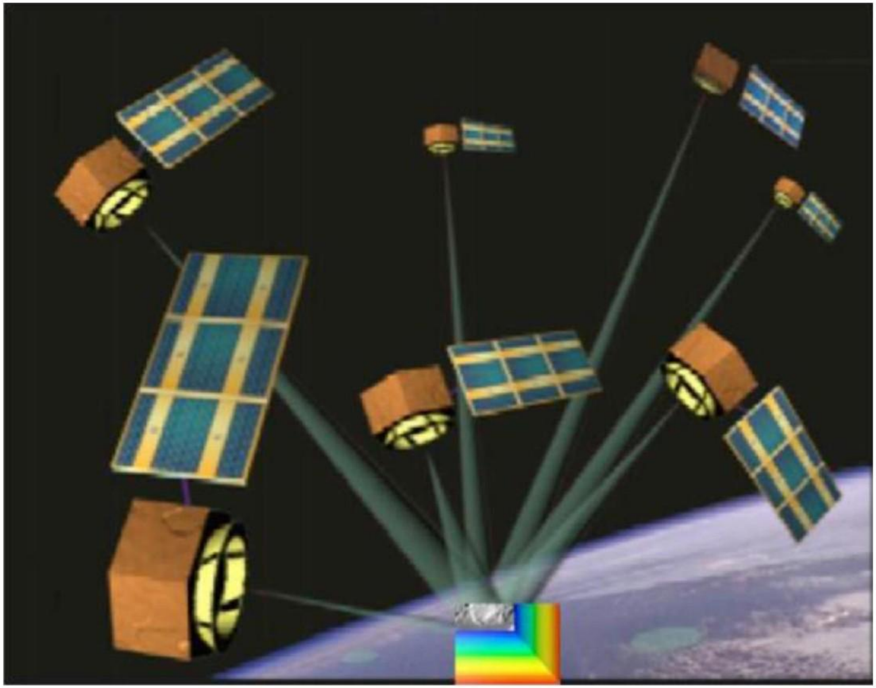
Cubesat Characteristics

- Mothership: S-band transmit and receive; directional antenna (i.e., attitude / antenna pointing requirements); high rate burst transmissions; transponder required if TDRSS tracking services required
- Subordinates: Proximity link comm only; GPS position determination

Constellation Characteristics

- One Mothership, however, multiple CubeSats have the ability to fulfill the role of Mothership
- Two or more Cubesat architectures (Mothership-capable CubeSats, subordinate Cubesats)

User Needs: A satellite Formation Flying - Making Multi-angular, Multi-Spectral Measurements



A satellite formation making multi-angular, multi-spectral measurements by pointing its spectrometers at the same ground spot, as it orbits the Earth (not to scale).

(Courtesy of Sreeja Nag, et al., sreejanag@alum.mit.edu)

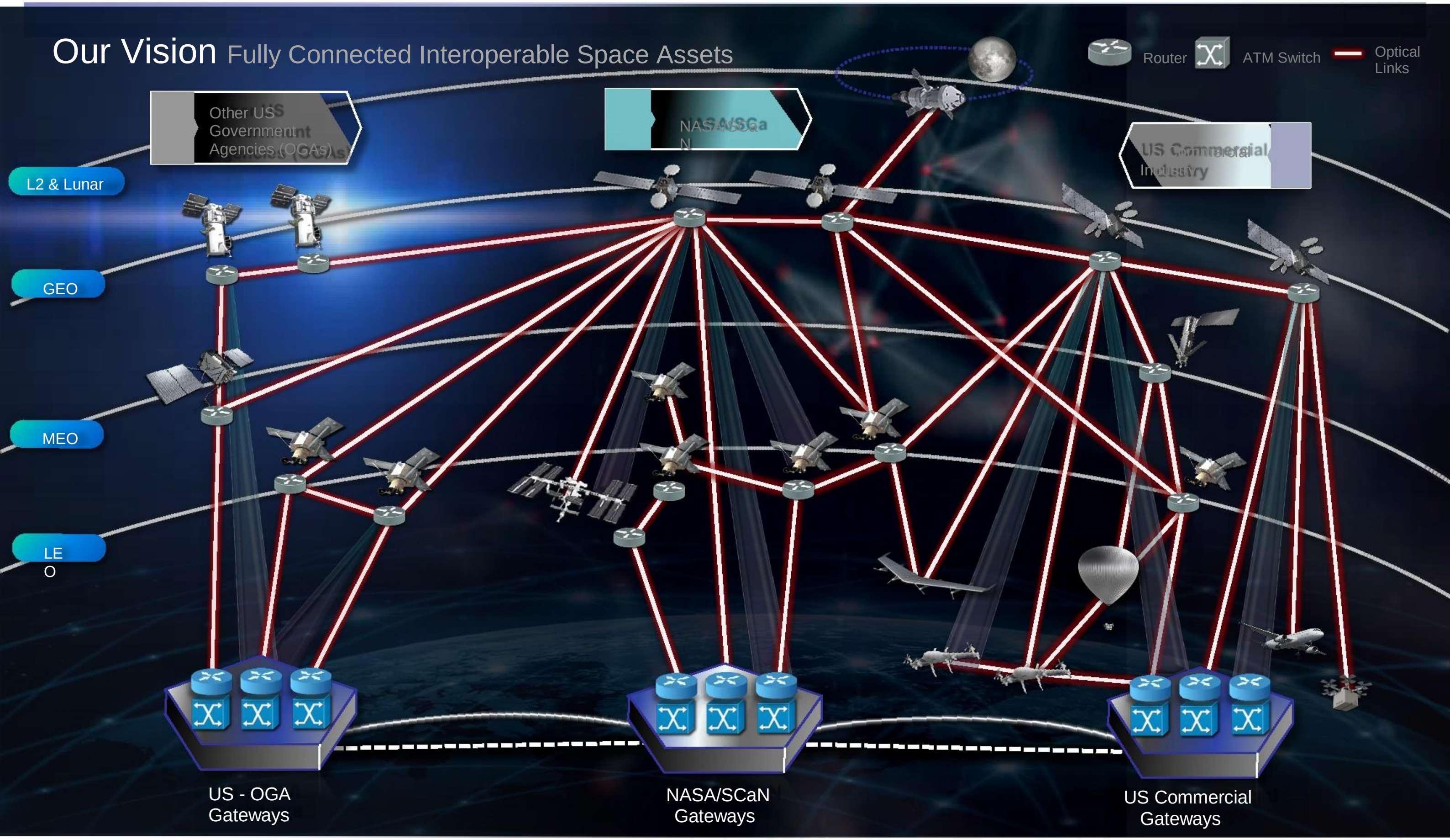
- Concerns:
  - Intelligent network management
  - Precision formation flying
  - Communication

Advances in Space Communication, Wireless Networks to Support Science Missions

Advances in Communication Systems

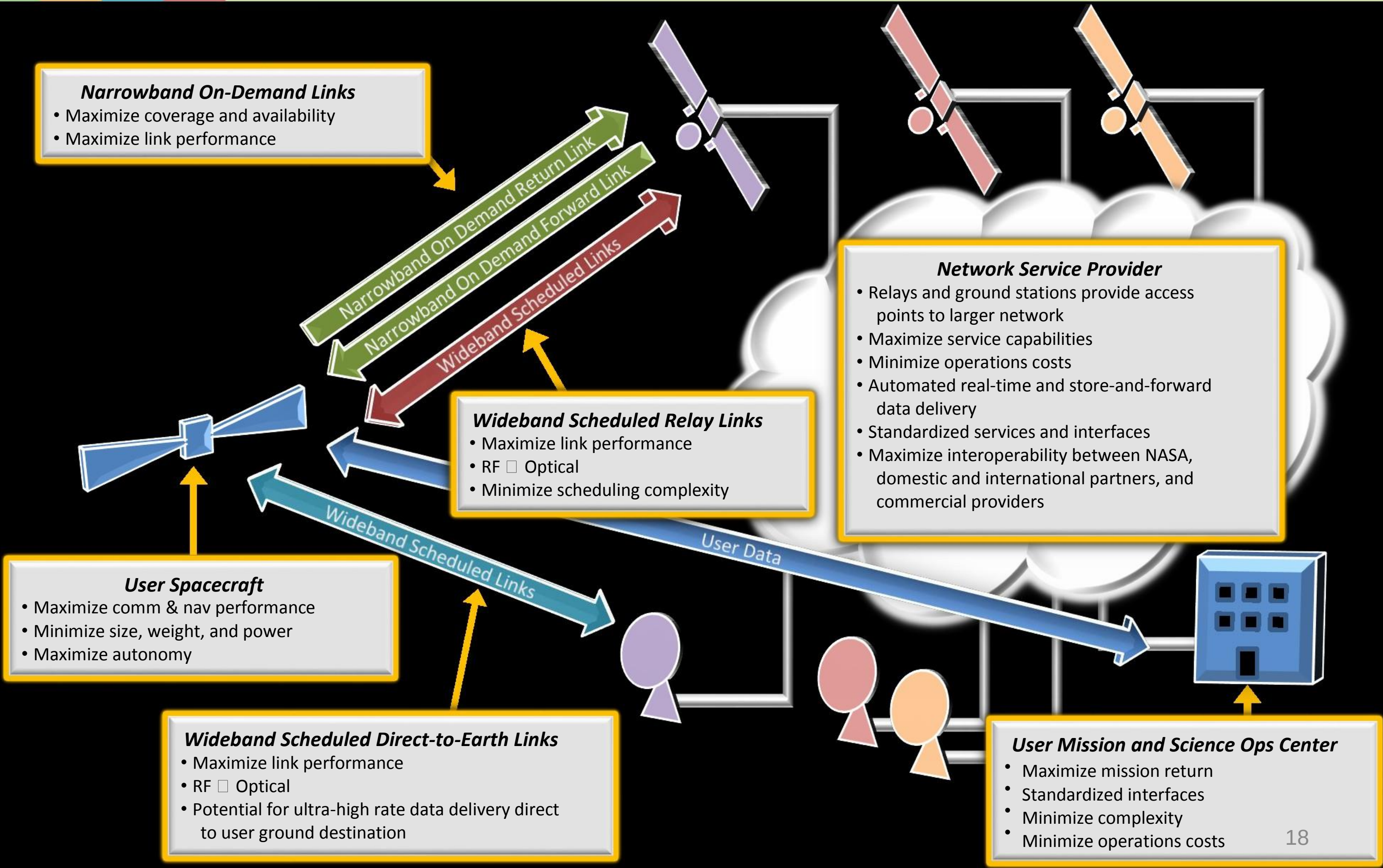
- Optical Communication and Future SCaN Integrated Network
- Standardization of Space Communication Protocols
- Space Mobile Network
- X-Ray Communication and Navigation
- Adaptive, Autonomous Networking Capabilities/Communication

Space Communications and Navigation



http://www.gps.gov/governance/advisory/meetings/2017-06/liebrecht.pdf

Space Mobile Network



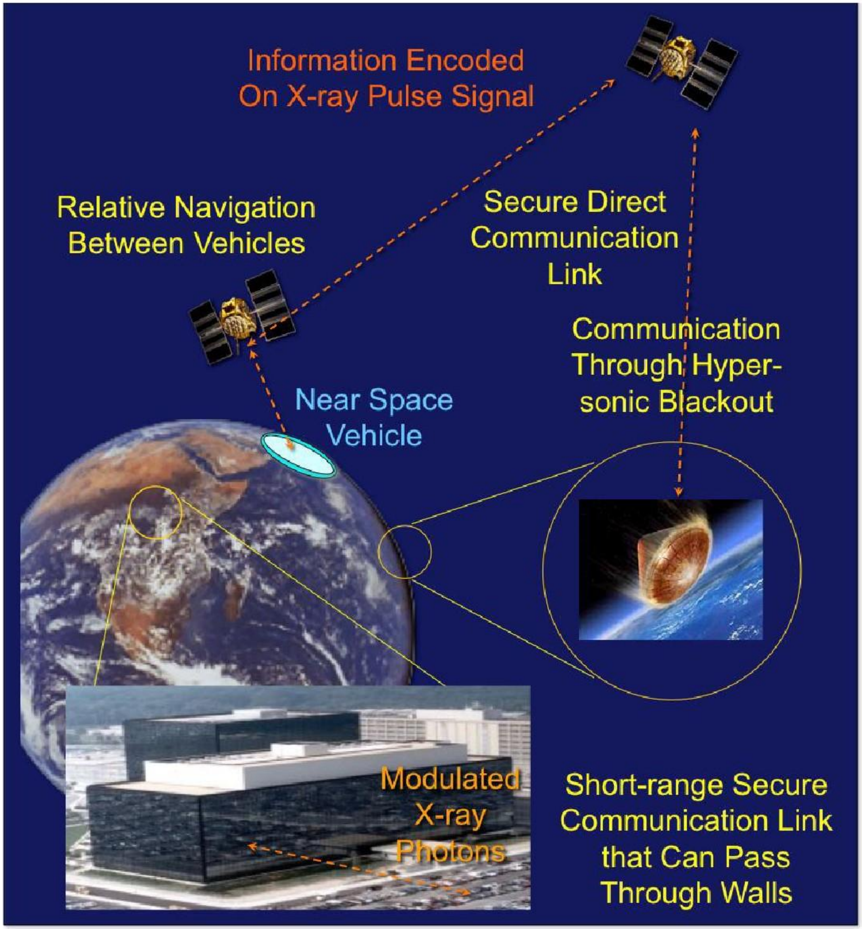
X-Rays Communication and Navigation

X-Rays as a medium for communication offer many applications:

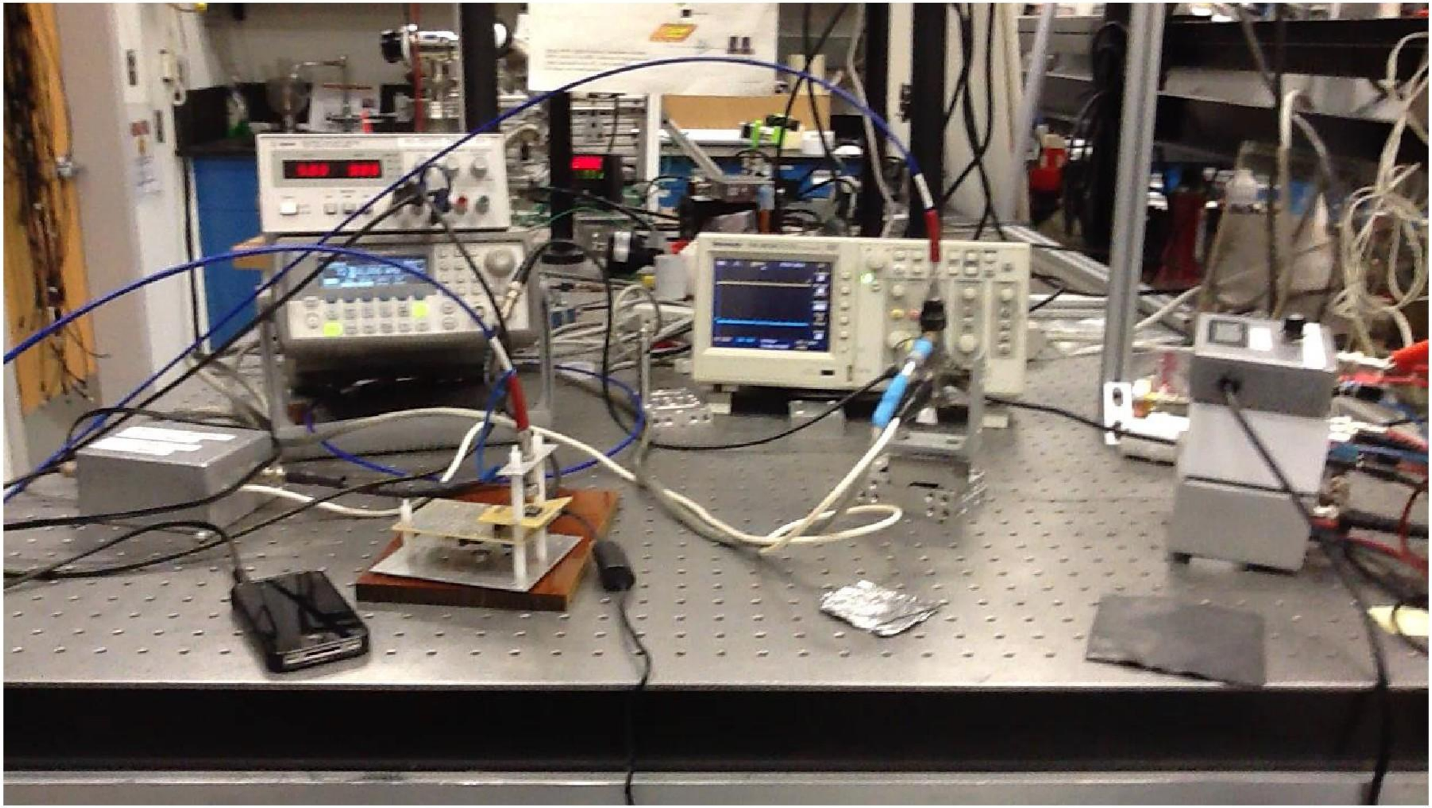
At Low energies:
-VERY tight beams for high data rates with the ultimate security

At high energies:
-Ability to penetrate RF shielding
-hypersonic vehicle link during blackout

(Courtesy of Keith Gendreau ,NASA/GSFC, keith.c.gendreau@nasa.gov)



XCOM Demo- iTunes over X-ray



(Courtesy of Keith Gendreau ,NASA/GSFC, keith.c.gendreau@nasa.gov)

Summary

- Advances in communication systems hardware will continue to improve planetary/interplanetary wireless internetworking fostering more science.
  - Adaptive and autonomous networking capabilities for improved wireless communication/sensor network management
- Some users for planetary surface sensors/instruments are calling for Ad hoc networks: self-aware nodes that can function as host and as a router, with navigation/mobility management features.
- Space wireless communication and internetworking is moving towards user initiated/driven topology.
- Standardization of protocols for interfacing sensor data to the physical radio/optical layer will increase sharing of resources.
- Space Mobile Network - a vision of interplanetary ad hoc, robust, and adaptable communication system webs.
- Optical communication will provide higher data rates for missions.