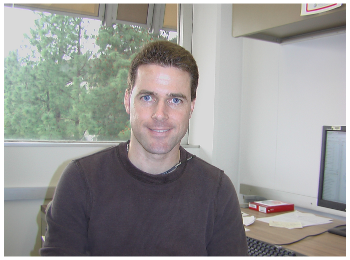
Telecommunications Architectures Group (332H)

- This group provides innovative contributions to improve and to evolve flight and ground communications, tracking, and network architectures. This includes:

- Define future deep space communications architecture to enable new NASA missions
- Evolve existing Deep Space Network capabilities to anticipate future needs (DSN 2.0)
  - Develop advance analysis, modeling, and simulation to support SCaN networks loading, coverage, link budget, networking studies to support current and future missions. Recent examples, Deep Space Capacity Study, Human Landing System Study (ongoing)
  - Develop new communication/tracking/navigation/radar approaches
- Support NASA's Lunar Relay Network for the era of human explorations. Examples:
  - Definition of relay services, e.g. <u>real-time</u> positioning service and time service
  - Concept of the advanced relay network architecture
- Support Mars Relay Network trade analysis and loading analysis. Examples:
  - Mars Sample Return support scenario analysis
  - MAVEN attitude and power constrain study
- Support DTN standards and research – energy-aware routing, cognitive DTN node management, distributed service manager, multi-copy LTP (smart ARQ), etc.

Group Members



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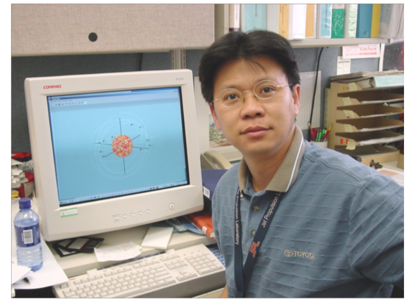

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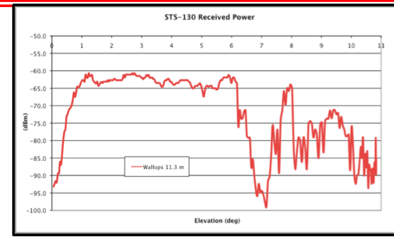
Communication and Network Architecting Process - Propagation, Link & Network/Traffic Characterization

Propagation Measurements And Data Collections



Measurements of physical phenomena

Mathematical Modeling

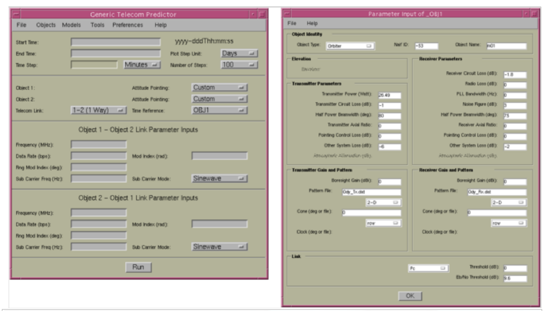
$$A_{normal}(p,\theta) \overset{(eqn.33)}{=} a(p)\sigma(\theta); \quad \sigma(\theta) = \sigma_{ref} f^{7/2} \frac{g(x)}{(\sin\theta)^{1.2}};$$

$$x \overset{(eqn.28)}{=} 1.22 D_{eff}^2 f \frac{\sqrt{\sin^2\theta + 2.35\times 10^{-4}} + \sin\theta}{2h_L};$$

$$g(x) = \sqrt{3.86(x^2+1)^{11/12} \sin\left(\frac{11}{6}\arctan\frac{1}{x}\right) - 7.08 x^{5/6}}$$

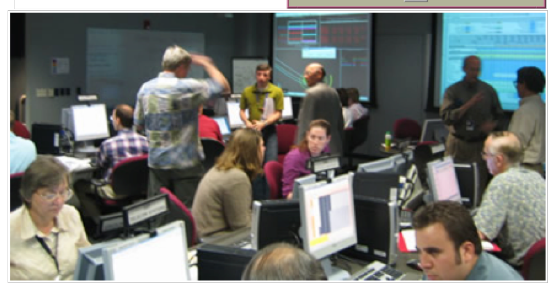
Finding the mathematical expression that 'best' represents the measured data

Incorporation of Models in Analysis, Modeling, and Simulation Framework



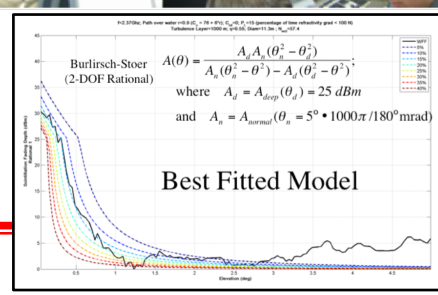
Developing high-fidelity analysis, modeling, and simulation tools and methodologies to support challenging communication and network architecture problems

People and Tool Deployment to Support Architecture Studies



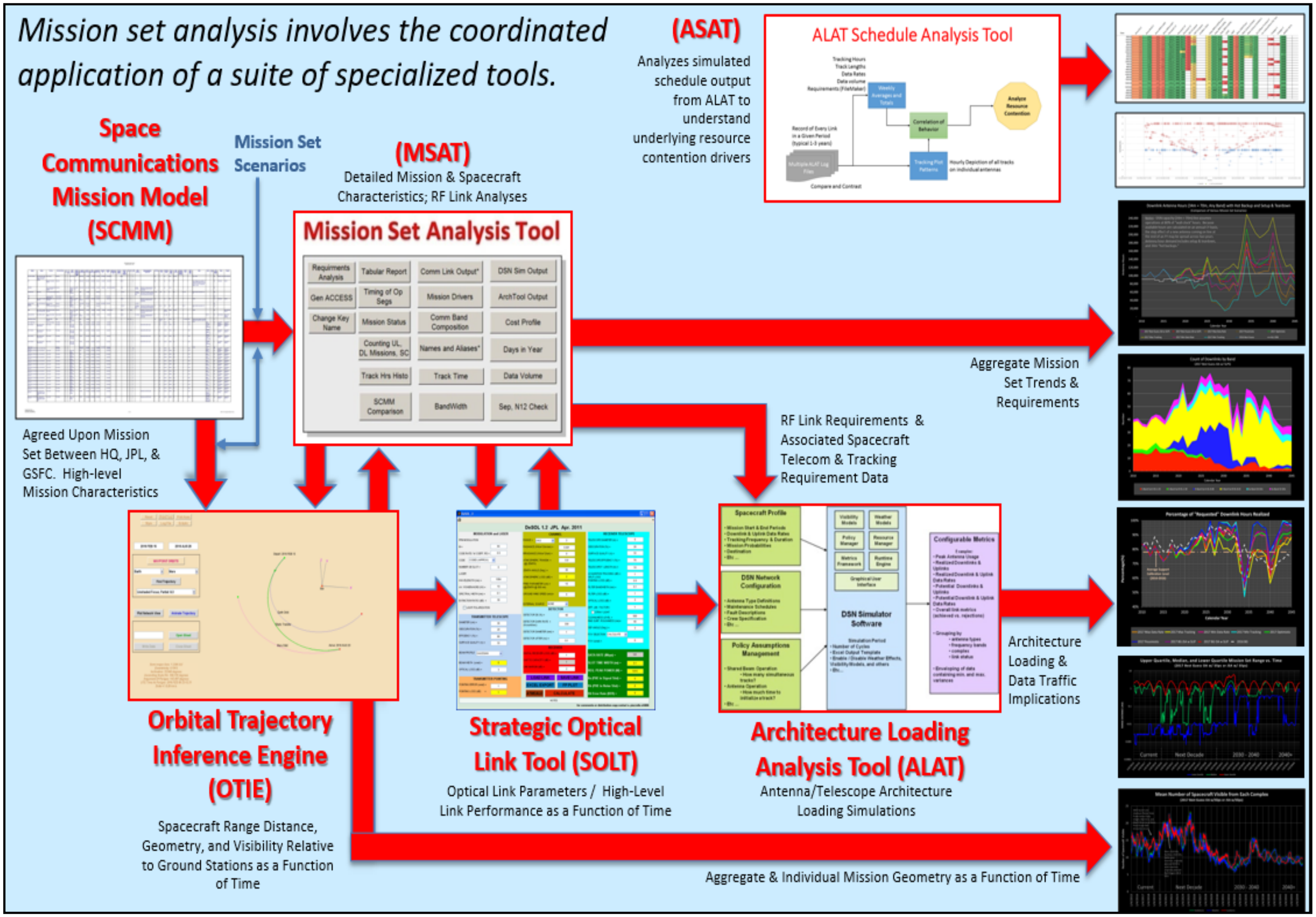
Support of architecture studies, mission design, and operation analysis

Team performs what-if studies, Design trade, and system optimization



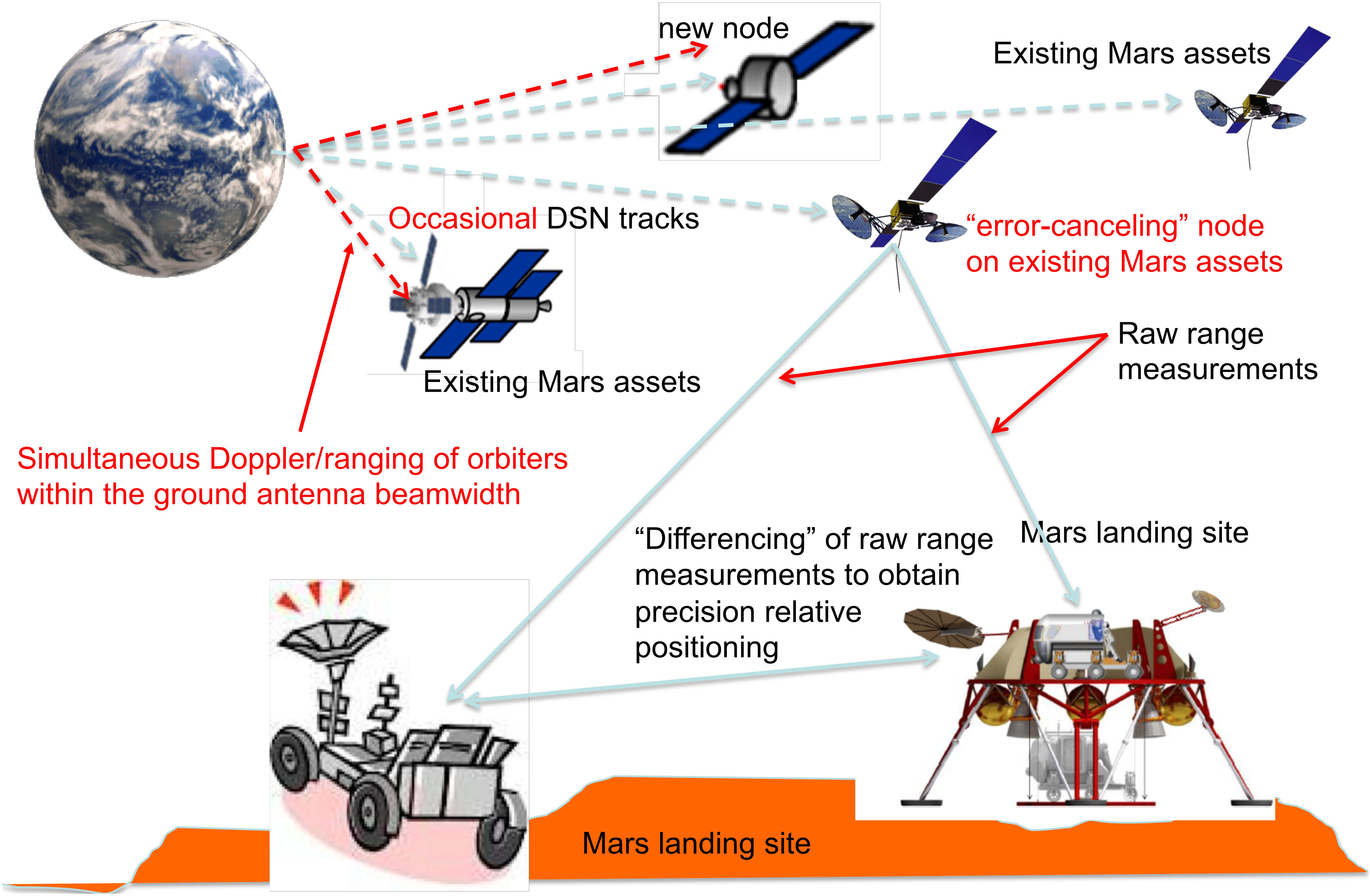
Performing what-if studies, design trade, and system optimization using using systematic analysis and modeling techniques

Mission Set Analysis Tool Suite



- Analyzed mission set scenarios typically include:
  - Best Guess
  - Optimistic
  - Pessimistic
  - Max Data Rate
  - Min Data Rate
  - Max Tracking
  - Min Tracking

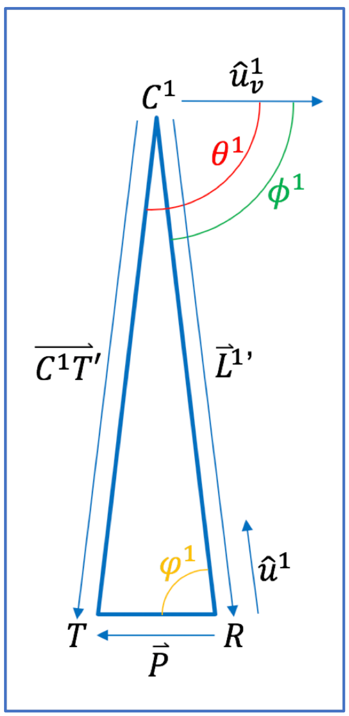
Mars Real-Time In-Situ Navigation - System Concept



Single-Satellite Real-Time Positioning for Moon, Mars, Venus, and Titan

- Novelty: use Doppler & range measurements in a proximity link for positioning
- Two methods:
  - Relative positioning: based on the Law of Cosines (LOC), e.g. lunar S. Pole with base station
  - Absolute positioning: based on theory of conics, Modified Conics Doppler Localization (MCDL), e.g. Venus balloon floating in atmosphere
- Doppler equation:

Relative: JDR-LOC



Visual Description of Doppler Localization with Law of Cosines. T is the user, R is the reference station, and C^1 is the satellite. $\hat{u}_v^1$ is the unit vector of the satellite's velocity vector and $\hat{u}^1$is the unit vector from the reference station to satellite 1.

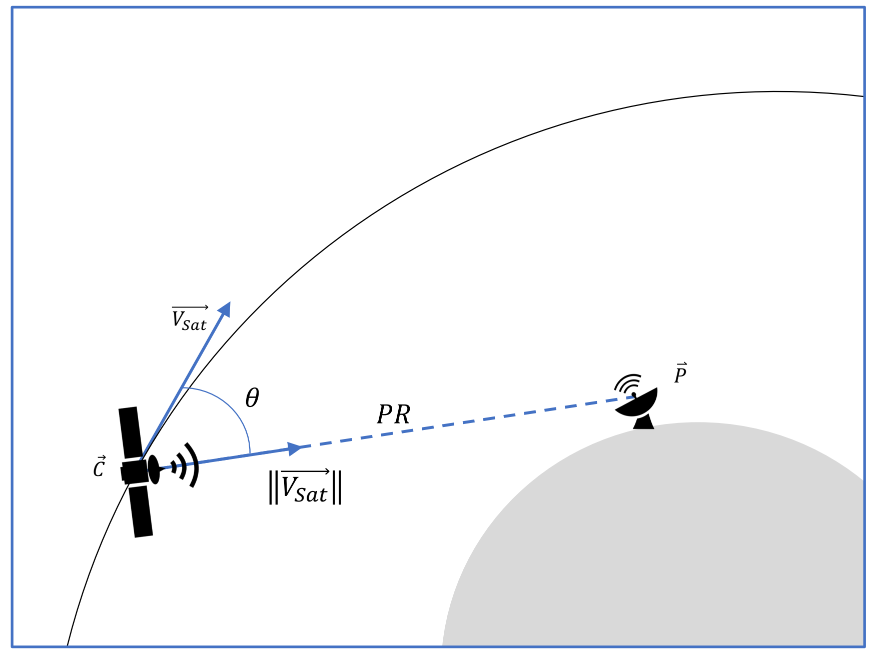
$$\left\|\vec{L}^{1\prime}\right\| = \frac{\vec{L}^1 \cdot \hat{u}_v^1}{cos\phi^1}$$

$$\left\|\overrightarrow{C^1T'}\right\| = \frac{\left(\vec{L}^1 + \vec{P}\right) \cdot \hat{u}_v^1}{cos\theta^1}$$

$$cos\varphi^1 = \frac{\vec{P} \cdot \hat{u}^1}{\left\|\vec{P}\right\|}$$

$$\left\|\overrightarrow{C^1T'}\right\|^2 = \left\|\vec{L}^{1\prime}\right\|^2 + \left\|\vec{P}\right\|^2 - 2\left\|\vec{L}^{1\prime}\right\|\left\|\vec{P}\right\|cos\varphi^1$$

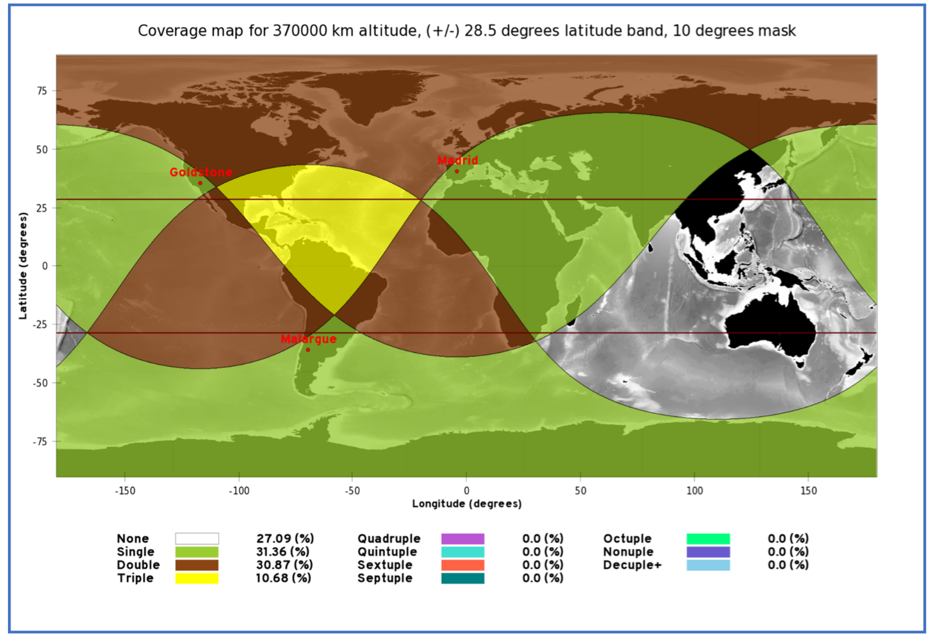
Absolute: JDR-MCDL



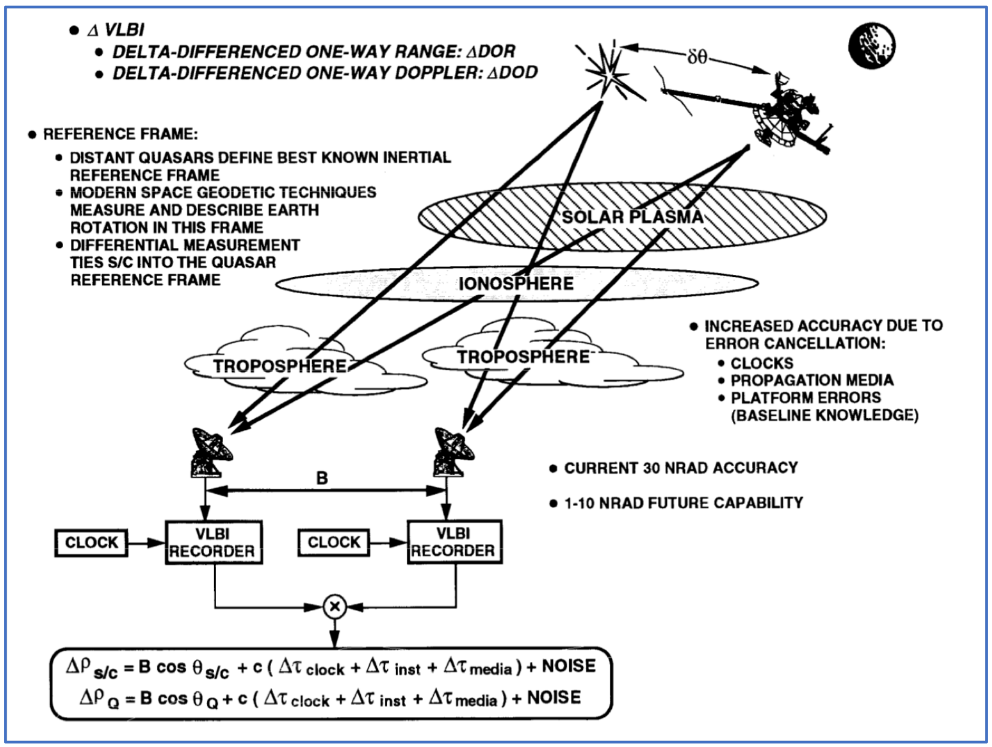
$$\frac{\vec{C} - \vec{P}}{PR} \cdot \frac{\overrightarrow{V_{Sat}}}{\left\|\overrightarrow{V_{Sat}}\right\|} = cos\theta = -\frac{RangeRate}{\left\|\overrightarrow{V_{Sat}}\right\|}$$

Real-Time Tracking/Navigation Using Simultaneous Baselines

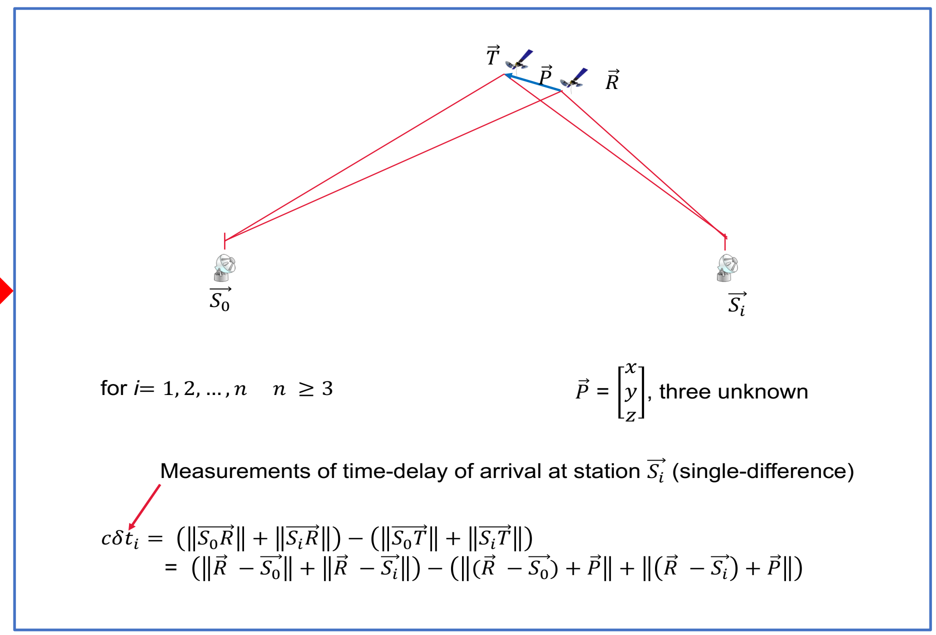
- Current DSN tracking techniques (Doppler, ranging, and ΔDOR) are non-real-time
- Human lunar exploration requires real-time tracking/navigation
  - Short light-time delay, ~1.5 seconds
  - Critical events are mostly power-flight: approach/docking, descent, descent, etc.



Simultaneous ΔDOR between 3 stations

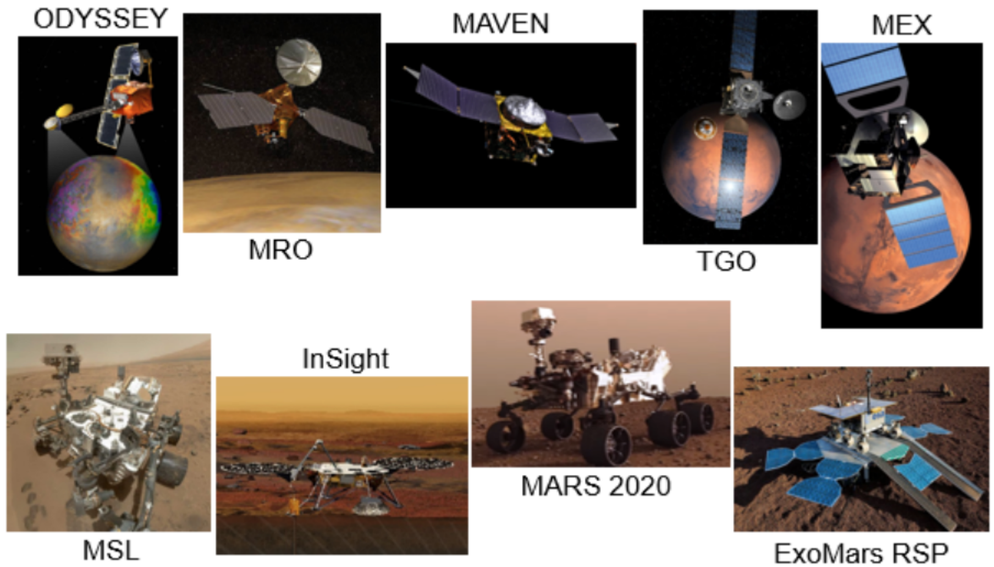


Current DSN's ΔDOR, 1 baseline (a pass) at a time



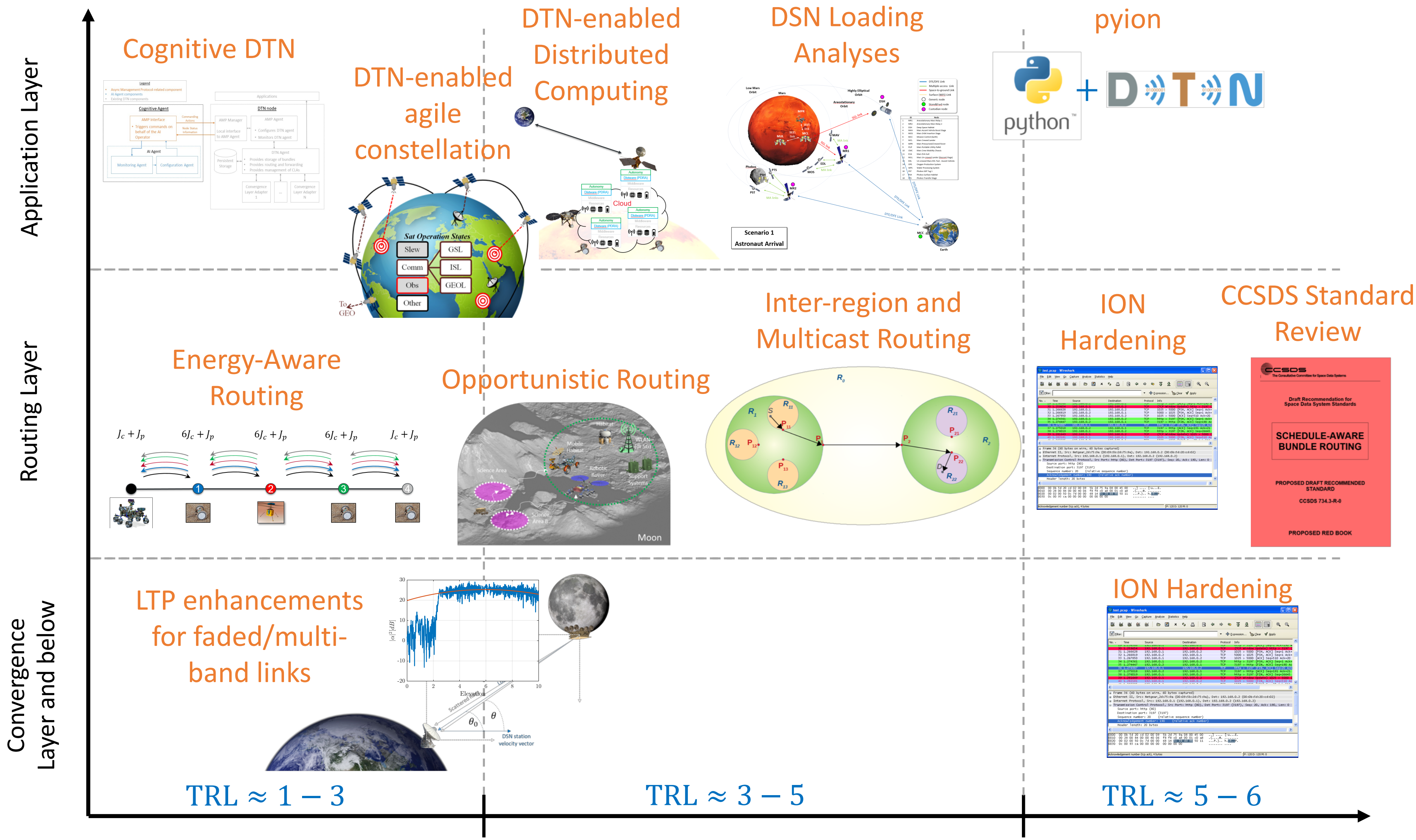
Differential positioning radar for GEO/Lunar

Mars Relay Network – Loading and Trade Studies



- Generate relay data throughput predicts between all surface assets and relaying orbiters.
- Take into account SC constraints such as radios, attitudes, earth-beta angle, canted angle, solar eclipses, antenna patterns, etc.
- Lay out the principal rules for relay and pass selection for each surface asset.
- Assess the sol-to-sol surface ops efficiency based on the Earth team’s planning time and schedule.
- Provide sol-to-sol data volume predicts for each Mars surface asset.
- Understand relay support load of the network.
- Develop strategies to enhance network relay efficiency.
- Study “what-if” scenarios, depending on the availability of the relay orbiters, orbital commitments, surface user priorities, etc.

Delay Tolerant Networking – Research Portfolio



- Understanding basic principles
- Understanding Potential Applications and benefits

- High fidelity system simulation/emulation/evaluation
- Add hardware-in-the-loop.

- System validation in simulated/emulated environment