COMMUNICATIONS & NAVIGATION

AN OUTSIDER'S GUIDE TO SCAN AND HOW TO TALK IN SPACE

(BECAUSE IN SPACE THEY CAN'T HEAR YOU SCREAM…)

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FIRST PRINCIPALS: WHAT DO I NEED?

Amongst the huge number of considerations when designing a mission, one of the most fundamental is that that of Communications and Navigation.

How to I talk to my spacecraft and instruments?
How do I know where it is, and how fast it is moving?
What is the right cadence for my communications and ranging needs?
How much data do I need/want/desire, and can I get it?
How robust is my system on-orbit and on the ground?
Do I <u>really</u> know my requirements?

WHAT DOES NASA HAVE TO OFFER?

NASA has 3 networks that are available to end-users.

- The Near Earth Network (NEN) consisting of multiple sites worldwide of moderate-sized antennas for comm & nav for spacecraft in Low Earth Orbit (LEO) and Geosynchronous orbit (GEO)
- The Space Network (SN) which consists of a series of on-orbit Tracking and Data Relay Satellites (TDRS) with dedicated ground stations
- The Deep Space Network (DSN) of 3 longitudinally equally spaced site of large-aperture antennas for comm and nav for objects beyond the moon

While all 3 are independent, they can work as a (somewhat) integrated system that allows for the comm and nav of a spacecraft as it moves from one regime to another. All 3 networks are managed by the Space Communications and Navigation (SCAN) Office at NASA HQ.

It is *very* worthwhile to start speaking with the SCAN folks as soon as one's concept starts to take shape. There is a mission commitment office within SCAN that is there to help.

WHAT ELSE DO I NEED?

Besides running the 3 networks, SCAN also has the responsibility to insure that a spacecraft/mission adheres to recognized international standards for communications transmissions (i.e. the format that the telemetry up/down is in) and spectrum (i.e. what frequency the spacecraft sending/receiving their telemetry on).

NASA is one of the leads for the development of the standards (via the Consultative Committee for Space Data Systems (CCSDS)), which insures that what is used will be understood as needed by other entities.

NASA through SCAN is mandated by statute to manage spectrum. It has the responsibility for Agency Spectrum Management, managing licensing of spectrum used by any NASA-sponsored spacecraft either through the FCC or the NTIA, and a major role in international spectrum management, both through US law and international treaty.

WHAT IS SCAN DOING NOW, AND SHOULD I CARE?

Yes, one *needs* to be aware of the evolution in communications! What is happening in the commercial sector will affect our ability to do future science.

Things are evolving very quickly: spectral bands are being licensed out the private sector as the need for personal/private bandwidth grows. This means that spectral regions now being used, like S-band (2-4 GHz), and X-band (8-12 GHz) are becoming much more restricted than even a decade ago.

It also means that we have to start serious thinking about moving to K_a-band (26.5-40 GHz) within the next 5 years. The advantage in moving to K_a is that it allows for higher bandwith, allowing more data to be transferred per unit time.

Optical Communications holds a promise of orders of magnitude increases in data transmission and accuracy in ranging, and has been successfully demonstrated from lunar orbit by the Laser Lunar Communications Demo (LLCD) on the LADEE mission at ~620 Mbps.

COMPARATIVE RF/OPTICAL REQUIREMENTS

Data Rate Mbps	0.38 AU	1 kg/m^2 2.67 AU	8.44 AU	26.7 AU	84.4 AU
4000	12.8 m, 2.5 kW				
3000	9 m,1 kW				
2500	6.5 m, 0.97kW	18.3 m, 2.5 kW			
2250		12.8 m, 2.5 kW			
1000	2.9 m,19 W	9 m, 1 kW	18.3 m, 2.5 kW		
500	2.5 m,131 W	6.5 m, 0.97 kW	12.8 m, 2.5 kW		
100	1.6 m, 64 W	4.2 m, 464 W	9 m, 1 kW	18.3 m, 2.5 kW	
50	1.3 m, 48 W	3.5 m, 335 W	6.5 m, 0.97 kW	12.8 m, 2.5 kW	
10	0.9 m, 20 W	2.3 m, 155	4.2 m, 464 W	9 m, 1 kW	18.3 m, 2.5 kW
5	0.7 m, 17 W	1.7 m, 142 W	3.5 m, 335 W	6.5 m, 0.97 kW	12.8 m, 2.5 kW
1		1.3 m, 48 W	2.3 m, 155	4.2 m, 464 W	9 m, 1 kW
0.5		1.3 m, 24 W	1.7 m, 142 W	3.5 m, 335 W	6.5 m, 0.97 kW
0.1		0.8 m, 17 W	1.3 m, 48 W	2.3 m, 155	4.2 m, 464 W
0.05			1.3 m, 24 W	1.7 m, 142 W	3.5 m, 335 W
0.01			0.8 m, 17 W	1.3 m, 48 W	2.3 m, 155
0.005				1.3 m, 24 W	1.7 m, 142 W
0.001				0.8 m, 17 W	1.3 m, 48 W
0.0005					1.3 m, 24 W
0.0001					0.8 m, 17 W

Distance (AU)	1000 Mbps		100 Mbps		10 Mbps	
	Diam (cm)	Opt Pwr (W)	Diam (cm)	Opt Pwr (W)	Diam (cm)	Opt Pwr (W)
1	26	10	11	5	7.5	1
2.68	50	19	26	7	14	2
6.47	95	30	48	12	22	5
11.09	130	50	65	20	31	10
21.1	200	75	106	30	50	13
50.36	350	160	200	50	100	23

The values of RF and optical mass vs. distance and data rate. With the distance fixed at 2.67 AU, the RF mass range is 100-175 kg for data rate of 1 Gbps; the corresponding optical mass is 42 kg.

The RF mass range for 100 Mbps is 35-51 kg and for 10 Mbps it is 12-16kg. In the latter two cases the corresponding optical masses are 26 and 14 kg, respectively. As distance increases, the difference between RF mass and optical mass requirements increases at all data rates.

Williams et al. (2007) NASA/TM-2007-214459
"RF and Optical Communications: A comparison of High Data Rate Returns from Deep Space in the 2020 timeframe."

OTHER CONSIDERATIONS -

While NASA SCAN has some statutory impositions on NASA-sponsored spacecraft, there are other considerations that can be kept in mind:

- If my mission is LEO, could I use private (either academic or commercial) assets for my comm and nav needs?
    - Yes, but It depends. CCSDS standards, security protocols, and compatibility tests may be needed for connections to NASA facilities.
- Is there a Customized Off The Shelf (COTS) solution for my needs?
    - Could be, and SMD and SCAN are working to see if a standard comm package can be developed for SmallSats and other spacecraft (like a standard K_a-Band transceiver.)
- Can I use foreign partnerships to be my comm and nav organization?
    - One needs to be *very* careful here: ITAR restrictions will likely apply to anything launched on a spacecraft. So while not impossible, it might be very hard to get export licenses, etc., depending on the partner organization.
- How well do I have to know my needs, and when do I need to know them?
    - The sooner one can nail down the comm and nav requirements the better. There is now an established SMD policy that mission-specific requirements, plus most compatibility testing that require special needs are born by the mission. (This is new in the last 2 years.)   One should not being using SCAN for developing comm protocols, but only I&T when one is really ready to go through I&T.

QUESTIONS?