GSAW2006
Ground System Architectures Workshop

JPL
Jet Propulsion Laboratory
California Institute of Technology

Weather-Related Service Management Working Group

Opening Remarks

Wallace Tai

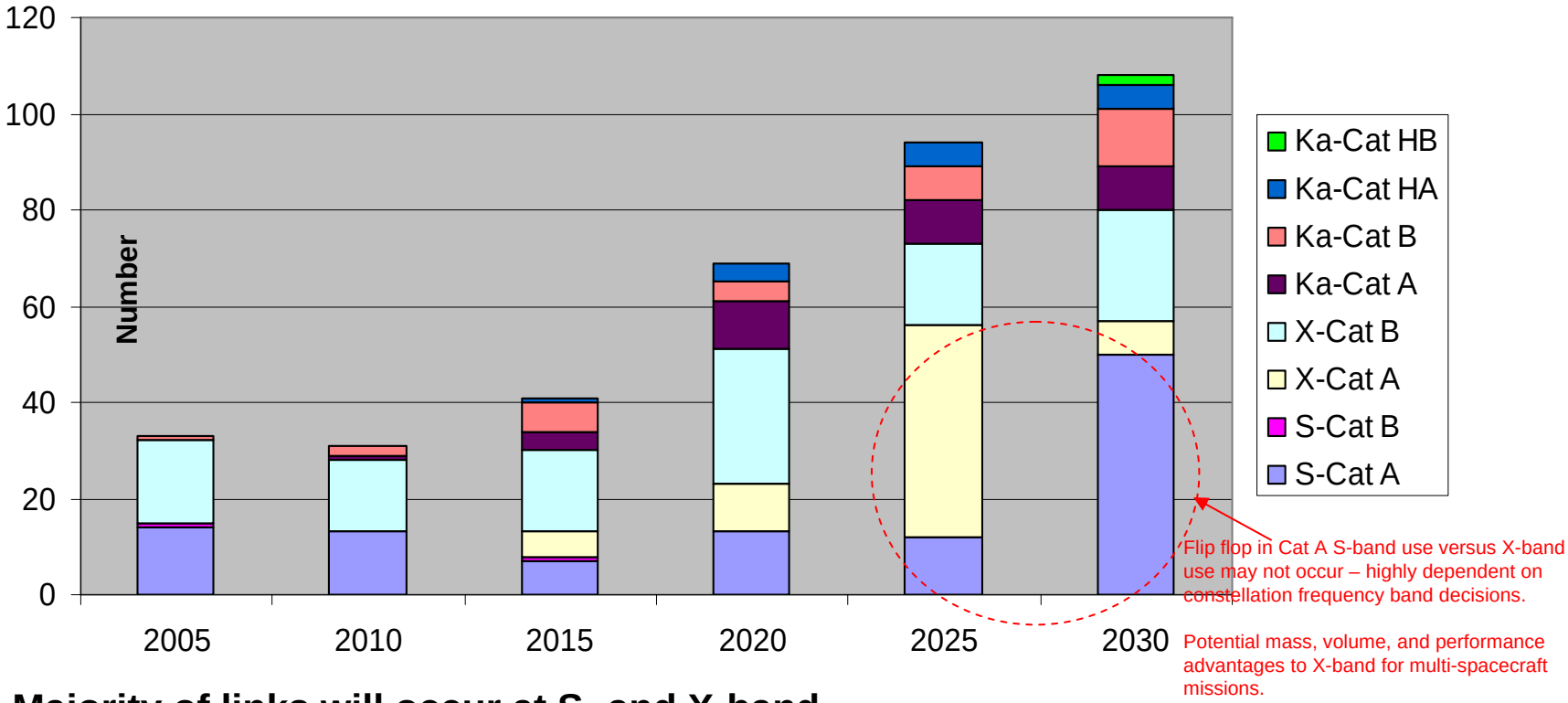
March 29, 2006

Ka Telecommunications for NASA Missions

- Trends of Frequency Band in NASA Space Missions
- Ka-band Missions Profile
- Operational Ka Capabilities in Deep Space Network (DSN)
- Key Challenges for DSN Operational Ka
- Summary

Downlink Frequency Band Trends

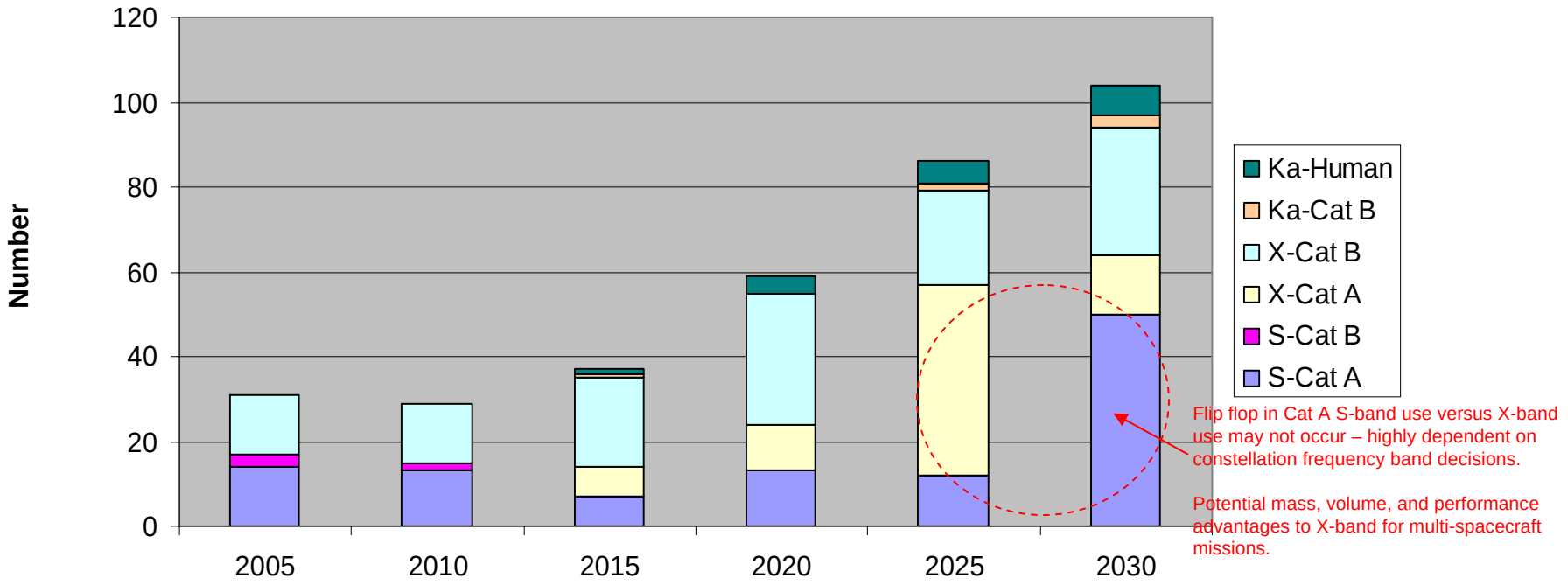
Projected Downlink Frequency Band Usage as a Function of Time



- **Majority of links will occur at S- and X-band.**
  - **S-band links overwhelmingly Category A**
  - **X-band links Category B with significant Category A growth**
- **Significant growth in the number of Ka-band links as a function of time.**
- **While fewer links at Ka-band than at S- and X-band, the higher associated data rates will, for deep space links, necessitate greater G/T on the ground.**

Uplink Frequency Band Trends

Projected Uplink Frequency Band Usage as a Function of Time



- **Just as with the downlinks, the majority of uplinks will occur at S- and X-band.**
  - **S-band links overwhelmingly Category A**
  - **X-band links Category B with significant Category A growth**
- **Human missions will drive most growth in Ka-band uplink.**
- **While fewer links at Ka-band, higher associated data rates will, for deep space links, necessitate higher EIRP on the ground.**

Ka-Band Missions* Relevant to DSN

Mission	Launch year	Frequency (GHz)	Data rate (Kbps)	Distance (AU)	G/T (dB/K)
Mars Reconnaissance Orbiter	2005	32	2600	0.6	53.59
Lunar Reconnaissance Orbiter	2008	26	100000	0.0027	38.48
Kepler	2008	32	2800	0.4	62.30
James Webb Space Telescope	2013	26	24500	0.01	35.46
Lunar Comm/NAV Relay #1	2014	26	100000	0.0027	35.31
Europa Geophysical Orbiter	2015	32	10	6.4	45.93
Mars Science Orbiter	2015	32	331	2.61	56.26
Space Interferometry Mission	2011	32	6400	0.3	57.71
Dark Energy Probe	2021	26	150000	0.01	45.54
Inflation Probe	2020	26	20000	0.01	42.14
Lunar Comm/NAV Relay 2	2017	26	125000	0.0027	42.90
Lunar Comm/NAV Relay 3	2020	26	125000	0.0027	42.90
Lunar Lander #5	2019	26	10000	0.0027	42.13
Lunar Lander #6	2020	26	10000	0.0027	42.13

Ka-Band Missions* Relevant to DSN

Mission	Launch date	Frequency (GHz)	Data rate (Kbps)	Distance (AU)	G/T (dB/K)
Terrestrial Planet Finder - Coronagraph	2016	26	64000	0.0117	43.28
Terrestrial Planet Finder-Combiner	2020	26	1000	0.0117	48.06
Con-07 Lunar Sortie 4 (CEV)	2019	37-38	50000	0.00257	33.52
Con-07 Lunar Sortie 4 (Lander)	2019	37-38	50000	0.00257	33.52
Con-07 Lunar Sortie 5 (CEV)	2019	37-38	50000	0.00257	33.52
Con-07 Lunar Sortie 5 (Lander)	2019	37-38	50000	0.00257	33.52
Mars Scout	2020	32	1140	2.2	59.69
Large UV/Optical Imager - Hub 1	2025	26	7500	0.01	36.53
Large UV/Optical Imager - Hub 2	2025	26	7500	0.01	36.53
SAFIR	2023	26	30000	0.01	50.44
Con-18 Lunar Outpost 7 (CEV)	2025	37-38	50000	0.00257	33.52
Con-18 Lunar Outpost 7 (Lander)	2025	37-38	50000	0.00257	33.52
Con-19 Lunar Outpost 8 (CEV)	2025	37-38	50000	0.00257	33.52
Con-19 Lunar Outpost 8 (Lander)	2025	37-38	50000	0.00257	33.52

Ka-Band Missions* Relevant to DSN

Mission	Launch date	Frequency (GHz)	Data rate (Kbps)	Distance (AU)	G/T (dB/K)
Lunar Cargo 4 (CEV)	2025	37-38	50000	0.00257	33.52
Lunar Cargo 4 (Lander)	2025	37-38	50000	0.00257	33.52
Interstellar Probe	2025	32	24000	2.5	70.80
Mars Atmospheric Survey	2026	32	8520	2.42	64.71
Mars Comm/NAV Relay #1	2024	32	125000	2.42	72.70
Mars Human Sub-ScaleTestbed1	2022	32	10000	2.42	66.91
Mars Human Sub-ScaleTestbed2	2022	32	10000	2.42	66.91
Solar Probe Imager/Telemachus	2022	32	3.2	6.2	48.80
Titan Explorer	2018	32	480	10.5	70.63
Human Lunar Base	2026	37-38	450000	0.00257	34.60
Con-28 Lunar Base-09 (CEV)	2030	37-38	50000	0.00257	33.52
Con-28 Lunar Base-09 (Lander)	2030	37-38	50000	0.00257	33.52
Con-29 Lunar Base-09 (CEV)	2030	37-38	50000	0.00257	33.52
Con-29 Lunar Base-09 (Lander)	2030	37-38	50000	0.00257	33.52

Ka-Band Missions* Relevant to DSN

Mission	Launch date	Frequency (GHz)	Data rate (Kbps)	Distance (AU)	G/T (dB/K)
Black Hole Imager	2028	26	15000	0.01	40.79
FIRSI (FAIR/DART) Science	2029	26	66000	0.01	44.35
Mars Comm/NAV Relay #2	2029	32	150000	2.54	73.91
Europa Astrobiology Lander	2024	32	6000	6.3	73.64
Farside Sentinel/Shields (lagging)	2026	32	2140	1.73	67.47
Farside Sentinel/Shields (leading)	2026	32	2140	1.73	67.47
Life Finder	2030	32	125000	0.05	52.81
First Human Mars Mission	2030	37-38	150000	2.54	69.90
Mars Human Precursor Outpost	2028	37-38	450000	2.54	77.16

*** Acknowledgment: Ka missions profile is based on the NASA Integrated Mission Set (IMS) and analysis on antenna links performed by Doug Abraham.**

DSN Operational Ka Capabilities
- Formulation Stage -

- Mars Observer (1993): Ka experiment for assessing Ka link performance; telemetry, Doppler and range
- Mars Global Surveyor (1996): Ka experiment for assessing Ka link performance; telemetry, Doppler and range
- Cassini (1997): Ka experiment for radio science; carrier only.
- Deep Space-1 (1998): Ka experiment for telemetry
- Mars Reconnaissance Orbiter (2005): Ka operational demonstration; telemetry, Delta DOR

Operational Ka Capabilities in Deep Space Network (DSN)

Complex	Station ID	Size	Type	Uplink	Downlink	
Goldstone	14	70m		S, X	S, X	
	15	34m	HEF	X	S, X	
	16	26m		S	S, X	
	24	34m	BWG	S, X	S, X, Ka*	*10/2006
	25	34m	BWG	X, Ka	X, Ka	
	26	34m	BWG	X	X, Ka	
	27	34m	HSB	S	S	
Canberra	34	34m	BWG	S, X	S, X, Ka	
	43	70m		S, X	S, X	
	45	34m	HEF	X	S, X	
	46	26m		S	S, X	
Madrid	54	34m	BWG	S, X	S, X, Ka*	*8/2007
	55	34m	BWG	X	X, Ka	
	63	70m		S, X	S, X	
	65	34m	HEF	X	S, X	
	66	26m		S	S	

DSN Operational Ka Capabilities
- What is in the Plan -

- By 2007, all six DSN 34m BWG antennas will be equipped with the Ka-band 32 GHz downlink capability to support deep space missions. The capability will be used to provide telemetry and Delta DOR services.

- By 2008, the Canberra DSN Complex will use Ka-band 32 GHz downlink capability at the Australian Narrabri antenna array as an alternate asset to support deep space missions. This capability is funded by NASA for providing telemetry service.

- By 2011, DSN will be equipped with the Ka-band 26 GHz downlink capability to support near Earth missions, e.g. James Webb Space telescope (or as early as 2010, if DSN is required to support Lunar missions).

- The Ka uplink capability at one of the 34m BWG stations at Goldstone will continue to be used for radio science service.

DSN Operational Ka Capabilities
- What is not yet in the Plan -

- Ka uplink capability for high rate video, e.g. HDTV, and data, e.g. command:
  - Needed to support human exploration
- Ka uplink and downlink tracking capability, i.e. ranging and Doppler data types for navigation:
  - No mission requirements yet

DSN Operational Ka Capabilities
- Challenges -

Effort is ongoing in DSN to overcome two main challenges to Operational Ka:

- Antenna pointing calibration -
  - Create, maintain, and improve an accurate antenna model
    - Ensure the signal beam is within the pull-in range of the monopulse.
    - Accurately point to the radio sources using blind pointing.
- Mitigation methods for adverse weather conditions -
  - Improve DSN Ka-band channel forecasting, i.e. forecasting of channel noise temperature.
  - Dynamic, adaptive actions to respond to adverse weather condition.

[Hence, the Weather-Related Service Management ……]