RF Communications

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General

- Two-year mission life
- Five-year goal
- X-band TWT A, designed for two-year mission life plus <18 month ground operation.
- Primary DSN resource is existing 34m BWG antenna system, supplemented by 34 m HEF/upgraded 34m BWG and 70 m systems as required

General (con't)

- Simultaneous X-band uplink, X-band downlink and tracking
  - Uplink
    - Normal mode: 125 bps
    - Emergency: 7.8125 bps
  - Downlink
    - Normal high rate science mode: >200 kpbs (when HGA pointing maintained within +0.1°)
    - Broadcast mode: 500 bps
    - Emergency mode: 10 bps

Uplink and Downlink

- Margin is 3 dB (min); 6 dB goal on uplink
- BER ≤10E–6

Downlink

- High Rate Science
  - 5 Gbit downlink per DSN contact for two year mission life:
    - Translates to 200 kbps in 7-hr downlink time
    - At two years distance from Earth for baseline trajectory:
      - Leading spacecraft (drift rate 20°/yr) is at 0.65 AU
      - Lagging (drift rate 28°/yr) is at 0.97 AU
    - DSN resources are 34 m BWG antenna system supplemented with 34 m HEF and 70 m
    - Post launch/early operations 800 kbps max
  - Rate 1/6, k = 15 convolutional coding + RS
  - Bit rate spacing 3 dB (nominal)

Downlink (con't)

- Broadcast mode:
  - 500 bps downlink rate:
  - R = 1/2, k =7 convolutional coding + RS
  - No uplink
  - X-band baseline:
    - Data downlinked through spacecraft HGA
    - TBS ground system, G/T is specified based on link
- S-band option:
  - Data downlinked through spacecraft dual feed X- and S-band HGA
  - NOAA ground system
- Emergency operation:
  - 34 m HEF and 70 m DSN resources

Navigation Support

- Navigation support via two-way Doppler tracking using JHU/APL developed non-coherent tracking technique:
  - For the two year mission support:
    - 0.1 mm/s (over 60 sec measurement interval) Doppler accuracy
    - $\pm$ 7500 km position accuracy
  - JHU/APL develop software. Where software resides (JHU/APL or JPL/DSN) will be negotiated with DSN during Phase A.
  - DSN provide to JHU/APL:
    - Product (raw Doppler information) from Radiometric Data Center
    - All spacecraft telemetry frames, frame number, frame synchronization time tags (a standard product)

RF Communications

Additional Information -
Preliminary Downlink Bit Rate Performance

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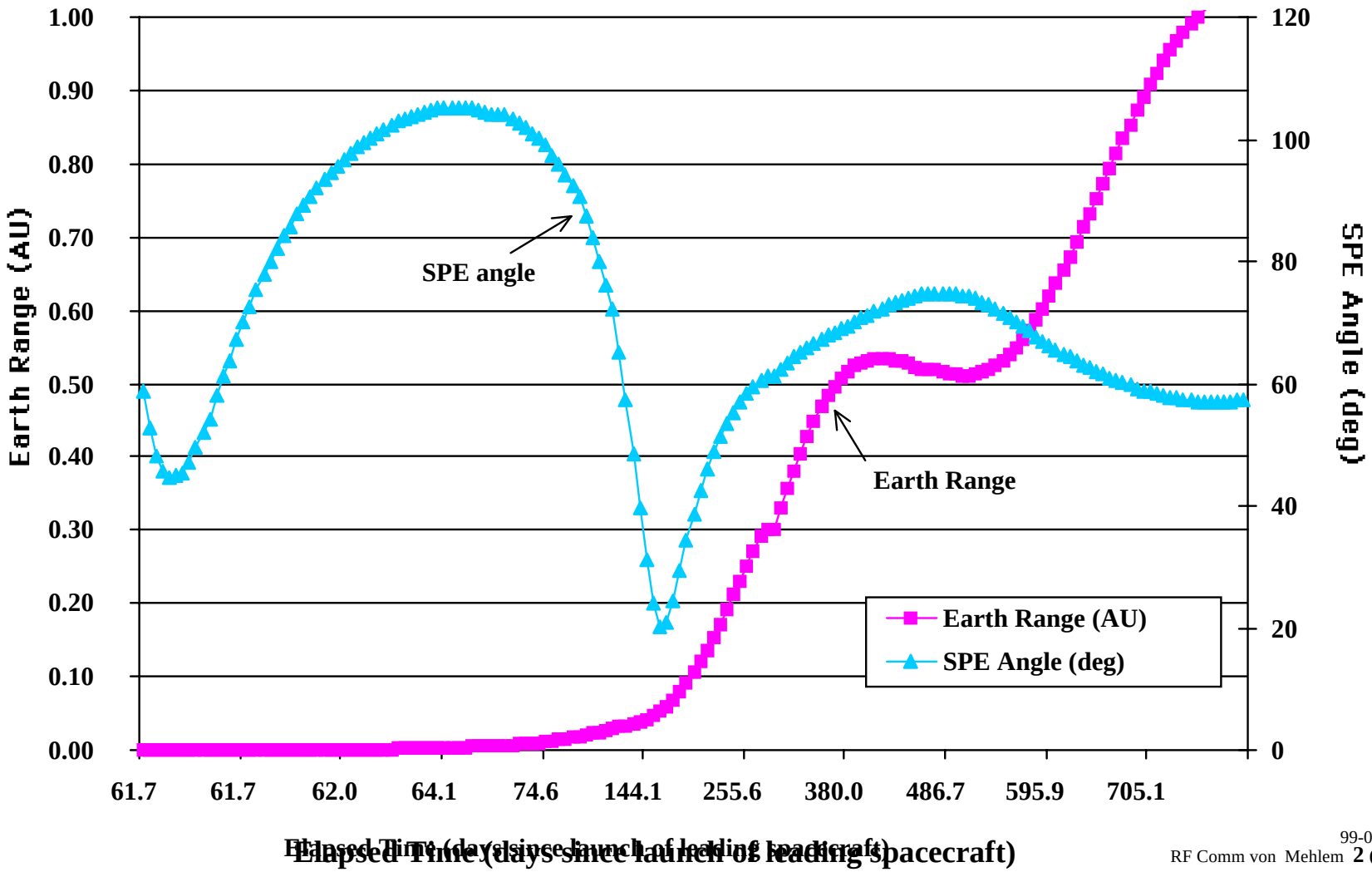
Solar Terrestrial Relations Observatory (STEREO)
Pre-Phase-A Requirements Review

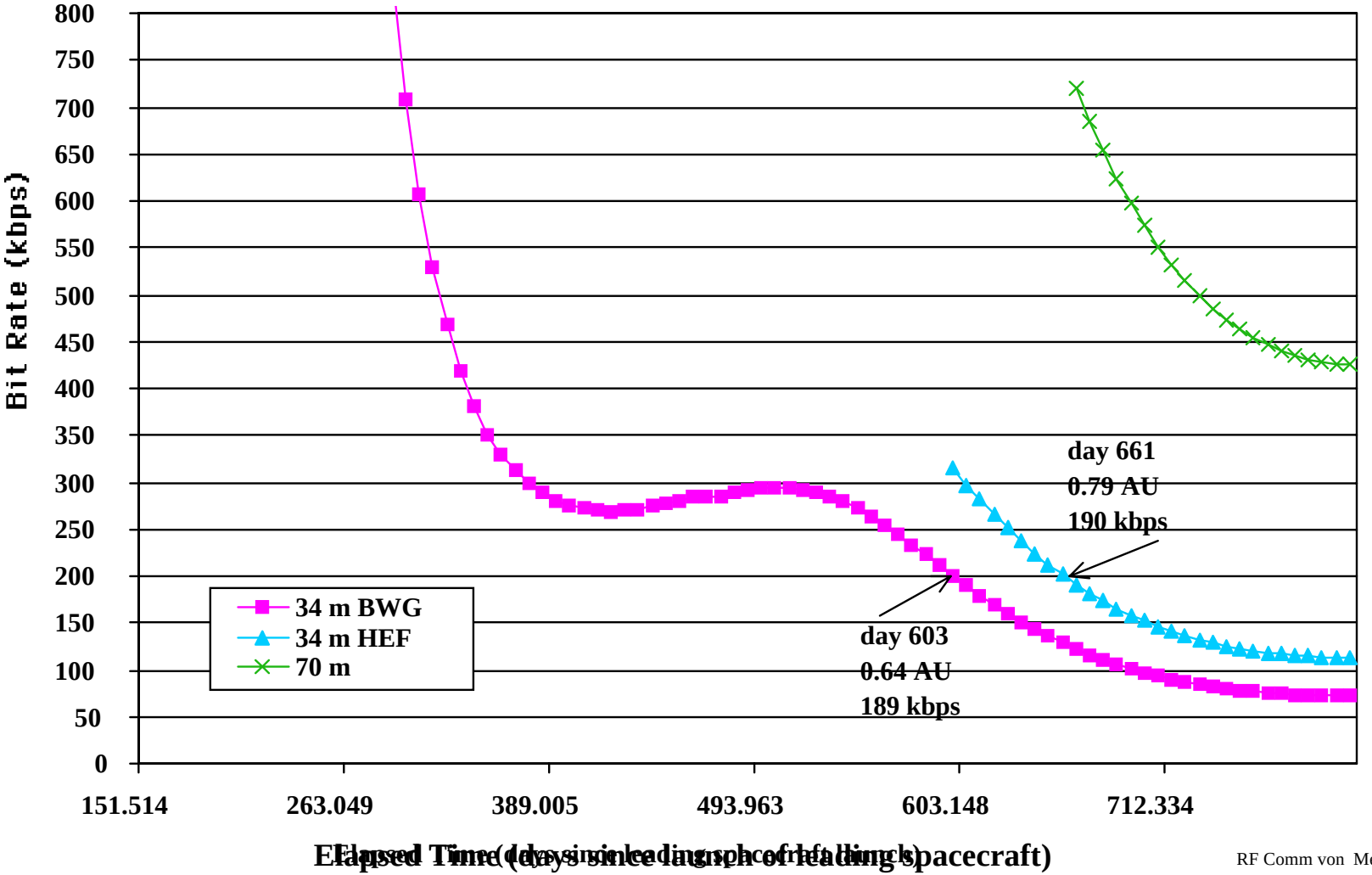
STEREO 28 deg/year Lagging Spacecraft

Earth Range and Sun-Probe-Earth Angle vs Elapsed Time since Leading S/C Launch



Solar Terrestrial Relations Observatory (STEREO)
Pre-Phase-A Requirements Review

STEREO 28 deg/year Lagging S/C
Bit Rate Capability S/C HGA to DSN Resources
(Preliminary)



Solar Terrestrial Relations Observatory (STEREO)
Pre-Phase-A Requirements Review

Bit rate performance deficiency summary for 2 degrees/day lagging spacecraft
(Baseline is 40 W TWTA; 1 m HGA; 3 dB link margin)

DSN antenna system	S/C HGA (m)	TWTA (w)	Day[1]	Earth Range (AU)	Bit Rate (kbps)	Link Margin (dB)
Last ~ 1 day[3] s						
34m BWG	1.1	40	603	0.64	189[2]	3
	1.1	40	603	0.64	200	2.7[2]
	1.1	40	668	0.81	115	3
	1.1	40	734 (2 years)	0.97	82	3
	1.75	40	734	0.97	200	3
34m HEF	1.1	40	661	0.79	190[2]	3
	1.1	40	734	0.97	128	3
	1.1	40	734	0.97	200	1
	1.4	40	734	0.97	200	3
	1.1	60	734	0.97	200	2.8[2]
70 m	1.1	40	734	0.97	485	3

Table notes:

1. Relative to launch for leading spacecraft (60 days earlier than lagging spacecraft)
2. Bit rate close to 200 kbps or margin close to 3 dB, within calculation assumptions for prephase A

- **28 DEG/YEAR LAGGIN SPACECRAFT TABLE ASSUMPTIONS:**
  - **SPE angle is <105 deg throughout mission. SPE is only >90 within first 25 days of launch of lagging spacecraft. HGA is used for downlink when SPE<90 deg. Extended HGA (with 2 dB degradation) is used for SPE between 90 and 105 deg.**
  - **Existing 34 m BWG performance is used**
- **CONCLUSION:**
  - **Link does not support 200 kbps using existing 34 m BWG from ~day 603 to ~day 734 (~131 days).**

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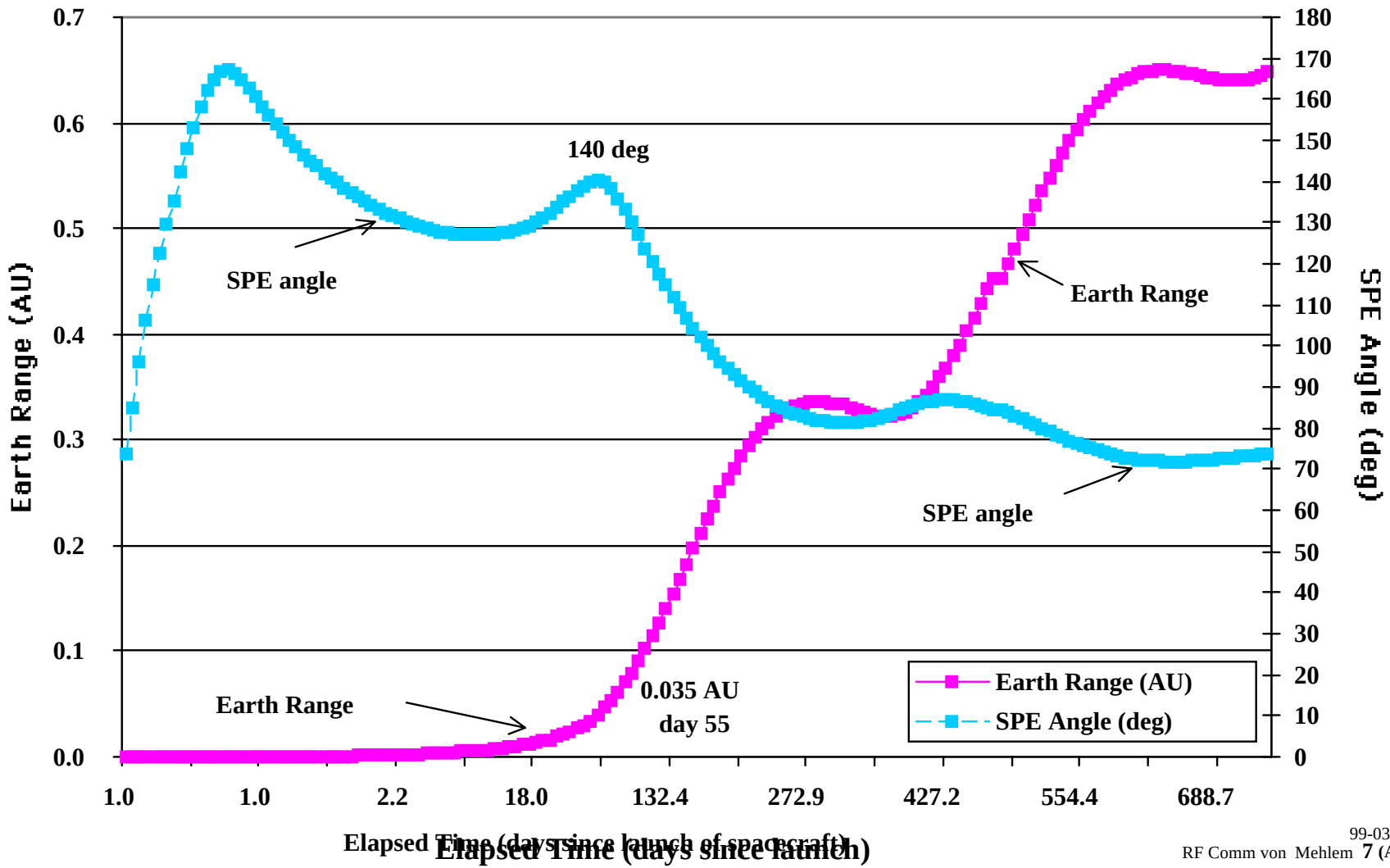
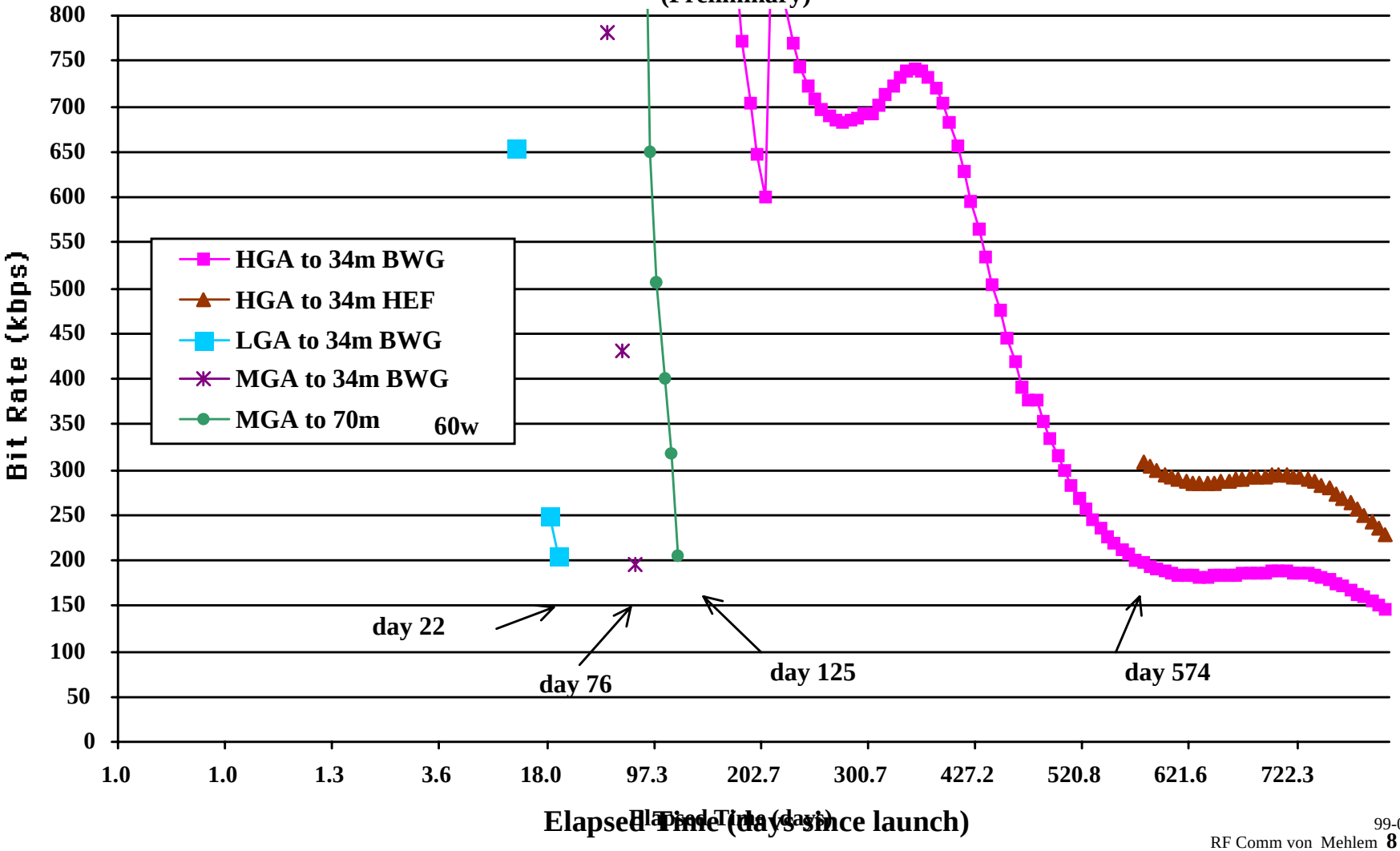
- **28 DEG/YEAR LAGGIN SPACECRAFT TABLE CONT:**
- **MITIGATION:**
  - **Increase HGA size (mechanical limitations with present launch vehicle)**
  - **From ~day 603 to ~661 (~58 days) use 34m HEF (if 34m BWG is upgraded, could use it since performance is expected to approach HEF performance). From ~day 661 to ~734 (~73 days) use 70 m DSN system. (cost)**
  - **Increase transmitter power (cost, dc power).**
  - **Accept lower link margin (risk).**

STEREO 20 deg/year Rate Leading Spacecraft
Sun Probe Earth Angle and Earth Range vs Elapsed Time since S/C Launch



Solar Terrestrial Relations Observatory (STEREO)
Pre-Phase-A Requirements Review

STEREO 20 deg/year Leading S/C- Bit Rate Capability S/C HGA to DSN Resources (Preliminary)



Solar Terrestrial Relations Observatory (STEREO)
Pre-Phase-A Requirements Review

Bit rate performance deficiency summary for 2.0 deg/yr leading spacecraft
(Baseline is 40 W TWTA; 1 m HGA; 3 dB link margin)

DSN antenna system	S/C antenna	TWTA (w)	Day[1]	Earth Range (AU)	Bit Rate (kbps)	Link Margin (dB)
Last ~ 2 days						
34m BWG	1.1 m HGA	40	574	0.63	196[2]	3[2]
	1.1 m HGA	40	800 (2 years)	0.72	149	3[2]
	1.1 m HGA	40	800	0.72	200	1.75
	1.1 m HGA	60	800	0.72	223	3
	1.3 m HGA	40	800	0.72	200	3.1
34m HEF	1.1 m HGA	40	800	0.72	234	3
Day ~76 to ~125[3]						
34m BWG	MGA	40	76	0.06	196[2]	3
	MGA	40	90	0.08	73	3
	MGA	40	125	0.14	14	3
70 m	MGA	40	111	0.11	336	3
	MGA	40	125	0.14	88	3
	MGA	40	118	0.13	200	1
	MGA	60	118	0.13	200	3

Table notes:

1. Launched 60 days earlier than lagging spacecraft. 800 day mission life envelopes 2 year for mission life for lagging spacecraft.
2. Within calculation assumptions for pre-phase A.
3. SPE is between 115 and 143 deg (~ 2 deg).

- **20 DEG/YEAR LAGGIN SPACECRAFT TABLE ASSUMPTIONS:**
  - **LGA (based on NEAR) is used post launch until ~day 20. MGA (based on NEAR fanbeam) is used ~day 20 to 125. HGA used from ~day 125 through end of mission. SPE is >90 from day 125 to 209.**
  - **Assume spacecraft is oriented about x-axis to maximize antenna gain towards earth.**
  - **Existing 34 m BWG performance is used**
- **CONCLUSION #1:**
  - **Link does not support 200 kbps using existing 34 m BWG from ~day 574 to ~day 800 (~226 days).**

- **20 DEG/YEAR LAGGIN SPACECRAFT TABLE CONT:**
- **MITIGATION:**
  - **Use 34m HEF (if 34m BWG is upgraded, could use it since performance is expected to approach HEF performance).**
  - **Increase transmitter power (cost, dc power).**
  - **Increase HGA size (mechanical limitations with present launch vehicle)**
- **CONCLUSION #2:**
  - **Link does not support 200 kbps using existing 34 m BWG from ~day 76 to ~day 125 (~49 days).**

- **MITIGATION:**
  - **Redesign NEAR fanbeam antenna to provide more gain over smaller beamwidth (mechanical limitations with launch vehicle and spacecraft hardware, cost) or design a new antenna (cost).**
  - **Use 70 m DSN system and higher power (cost, dc power).**
  - **Use 70 m DSN system and accept lower link margin (cost, risk).**
  - **Slew spacecraft to direct HGA at earth (loose science during downlink)**
  - **Redesign trajectory to move second peak of high SPE earlier in mission (may not be possible, science impact).**
  - **Have second small (~9 in) gimballed dish (mechanical constraints on spacecraft, costly.**