Jet Propulsion Laboratory
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WFIRST CGI Detector Radiation Environment

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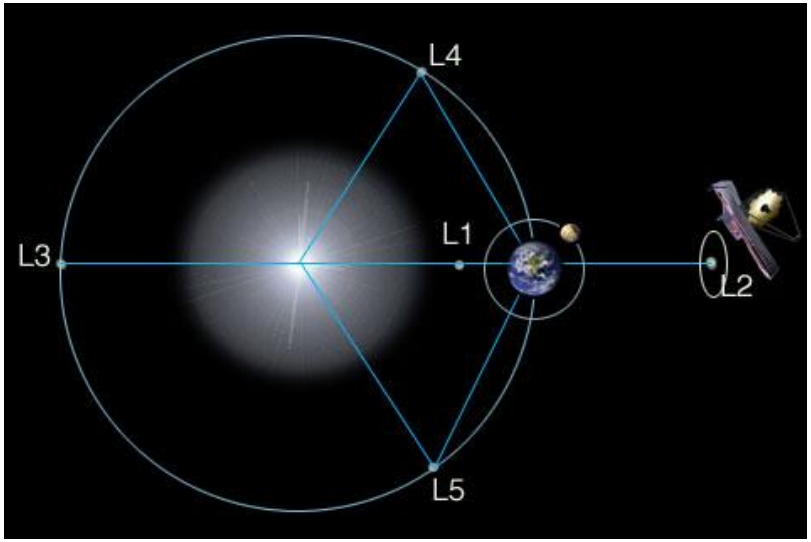
Outline

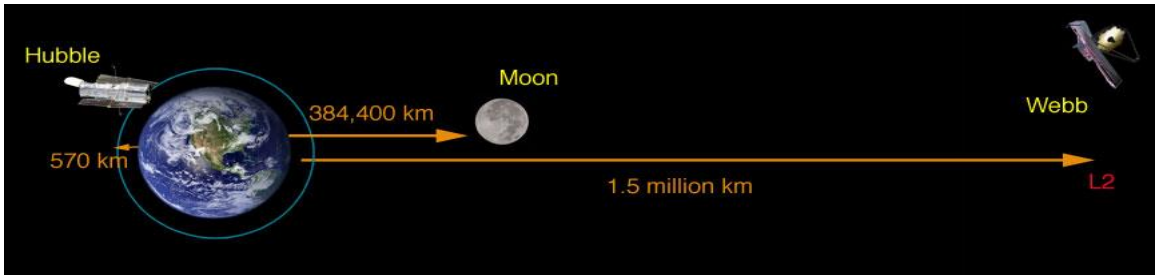
- L2 Radiation Environment
  - 6 year mission in an L2 orbit
  - Solar flare protons
  - Galactic Cosmic Rays (GCR)

- Radiation Transport Calculation

L2 Orbit

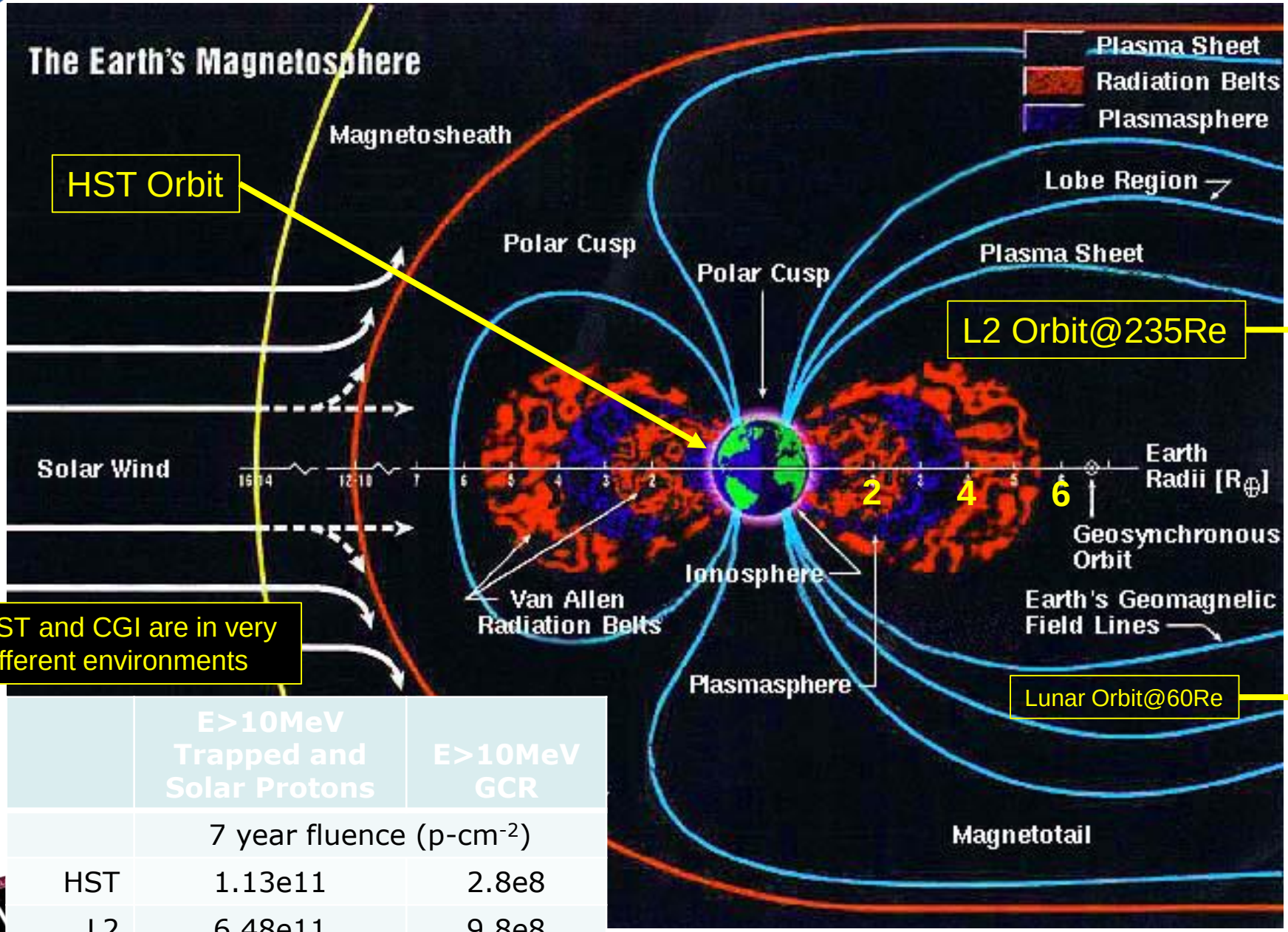
The relative location of the L2 point with respect to the Sun and Earth





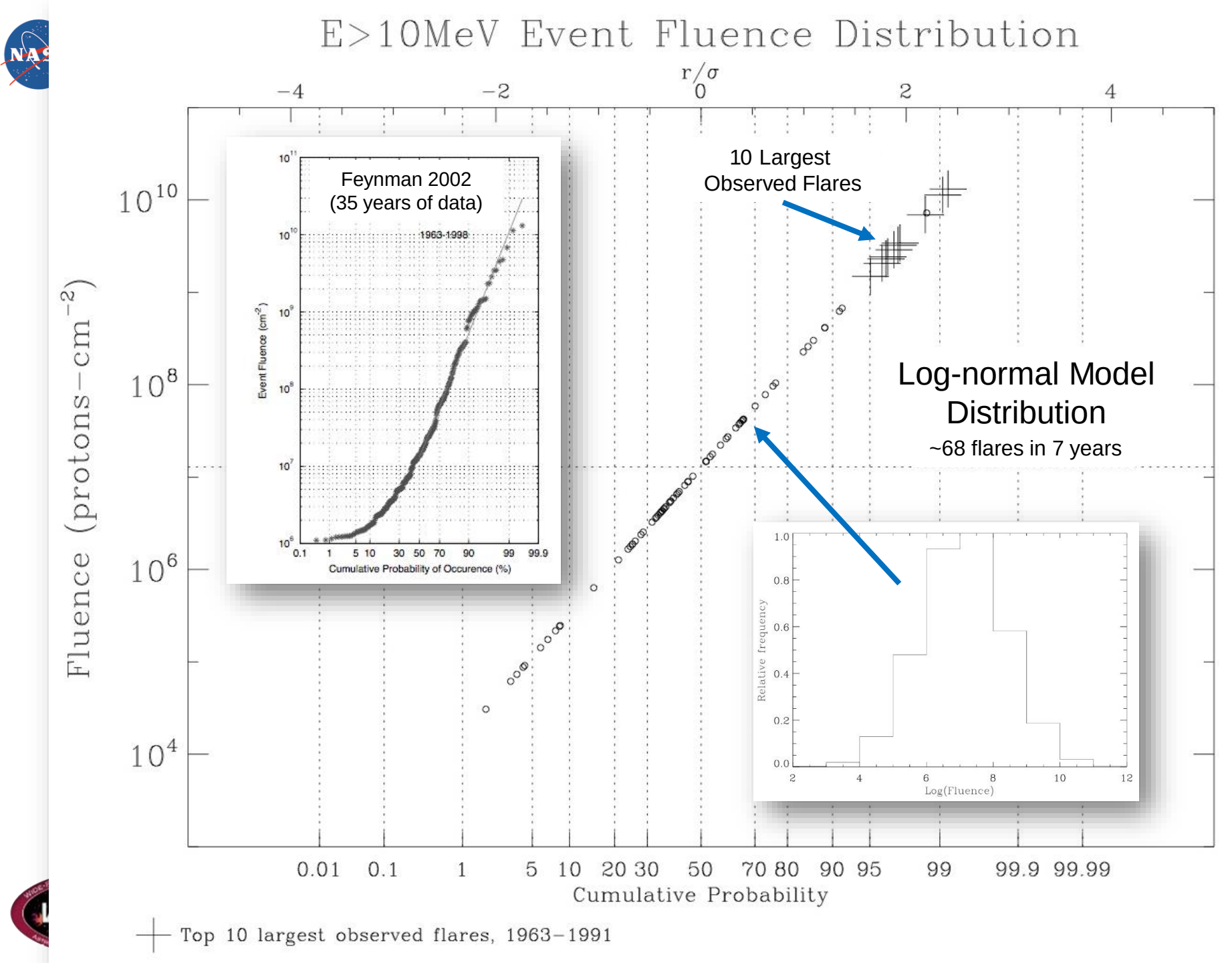
L2 Radiation Environment

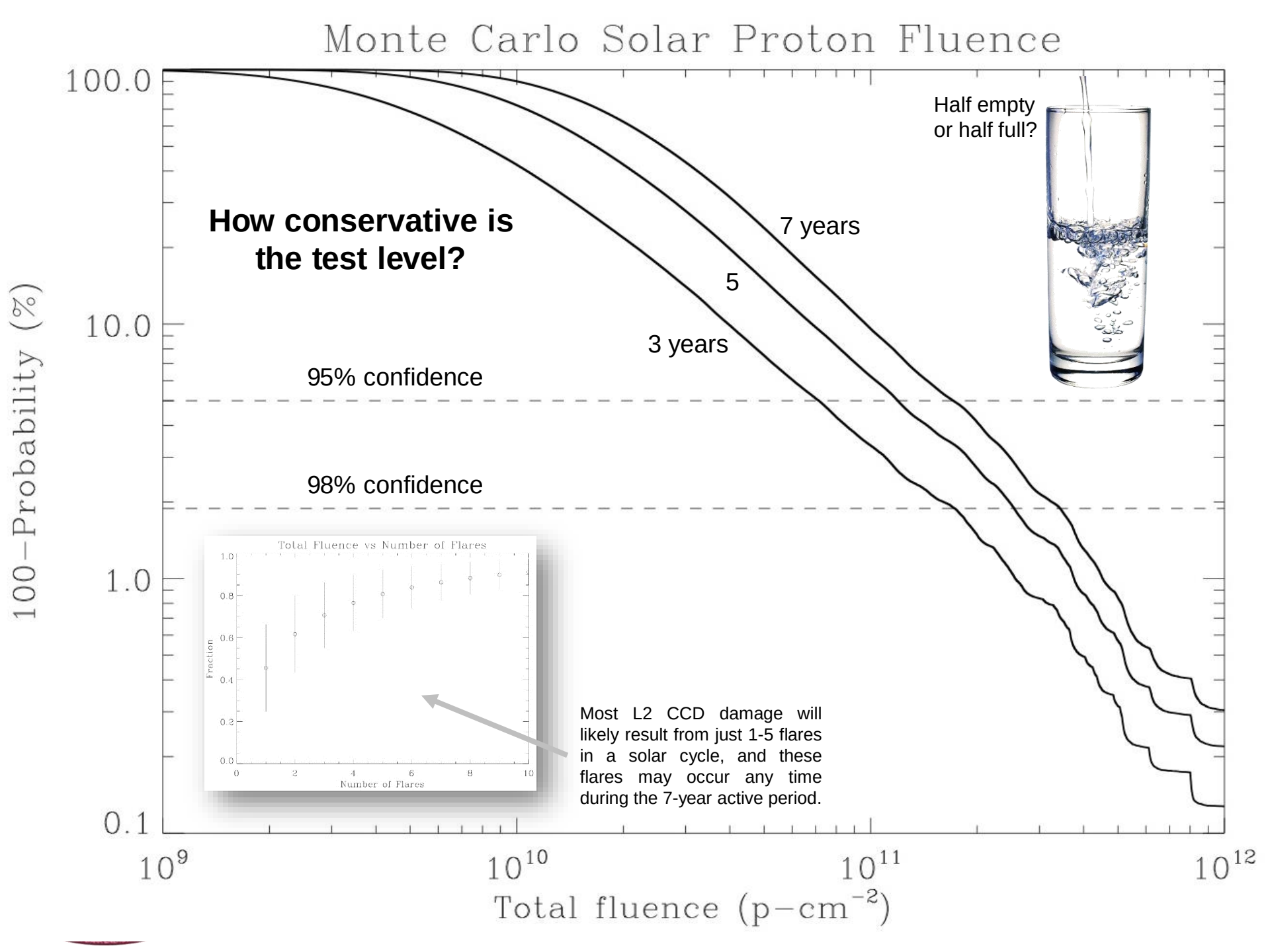
- The dominant radiation source is solar protons from Solar Energetic Particle Events (Solar Flares)
- Protons fluence from Galactic Cosmic Rays (GCRs) is 3 order of magnitudes lower than solar protons

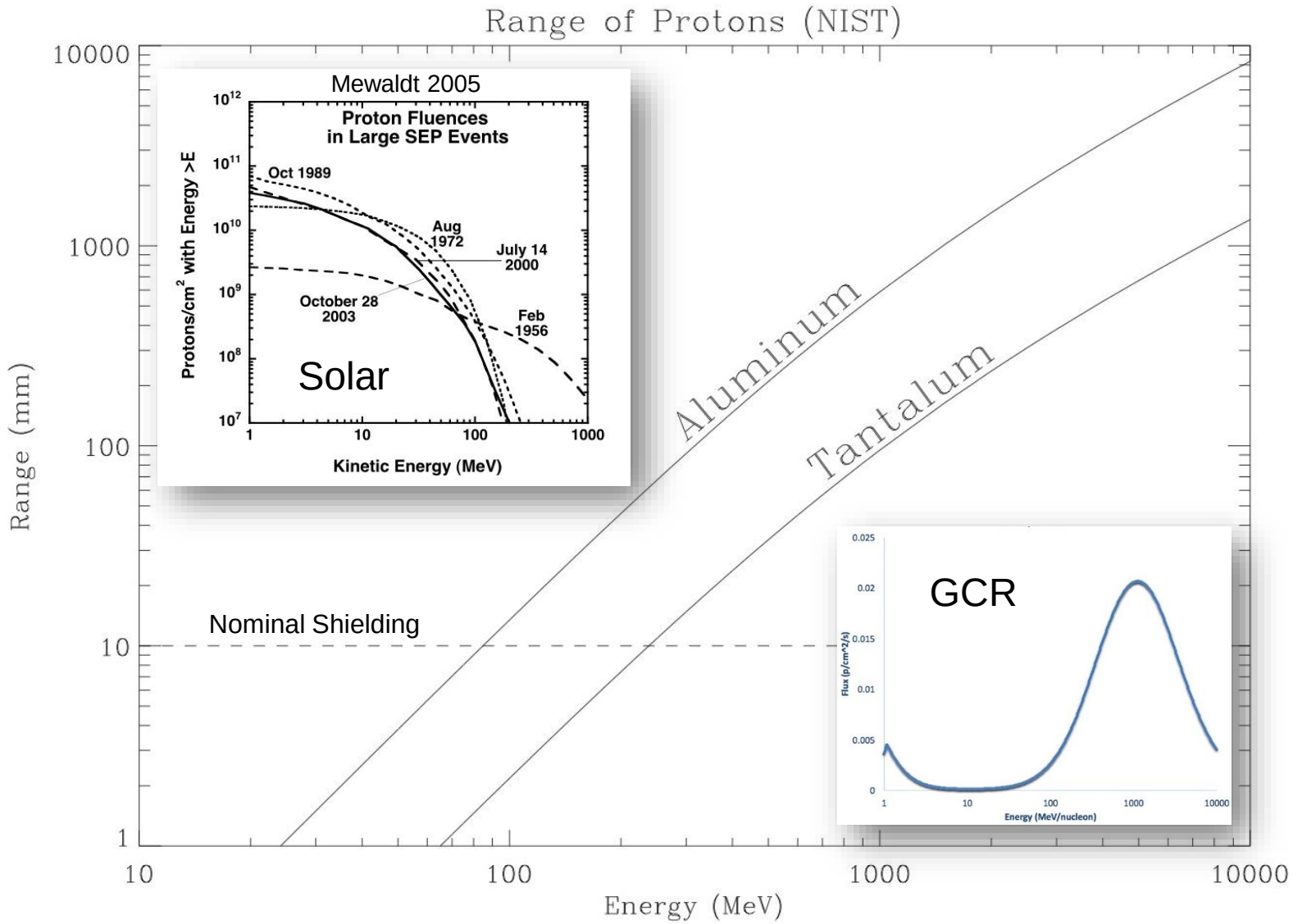


HST and CGI are in very different environments

	E>10MeV Trapped and Solar Protons	E>10MeV GCR
	7 year fluence (p-cm^{-2})	
HST	1.13e11	2.8e8
L2	6.48e11	9.8e8


E>10MeV Event Fluence Distribution
r/σ
−4
−2
0
2
4
Fluence (protons−cm^{-2})
10^{10}
10^{8}
10^{6}
10^{4}
0.01
0.1
1
5
10
20
30
50
70
80
90
95
99
99.9
99.99
Cumulative Probability
Feynman 2002
(35 years of data)
1963-1998
Event Fluence (cm^{-2})
Cumulative Probability of Occurence (%)
10 Largest
Observed Flares
Log-normal Model
Distribution
~68 flares in 7 years
Relative frequency
Log(Fluence)
Top 10 largest observed flares, 1963−1991


Monte Carlo Solar Proton Fluence
100.0
10.0
1.0
0.1
100−Probability (%)
How conservative is the test level?
7 years
5
3 years
95% confidence
98% confidence
Half empty or half full?
Total Fluence vs Number of Flares
Fraction
Number of Flares
Most L2 CCD damage will likely result from just 1-5 flares in a solar cycle, and these flares may occur any time during the 7-year active period.
10^9
10^{10}
10^{11}
10^{12}
Total fluence (p−cm^{-2})


Range of Protons (NIST)
Range (mm)
Energy (MeV)
10000
1000
100
10
1
10
100
1000
10000
Aluminum
Tantalum
Nominal Shielding
Mewaldt 2005
Proton Fluences
in Large SEP Events
Protons/cm² with Energy >E
Oct 1989
Aug
1972
July 14
2000
October 28
2003
Feb
1956
Solar
Kinetic Energy (MeV)
GCR
Flux (p/cm^2/s)
Energy (MeV/nucleon)

Radiation Level Calculation

- Estimate the L2 environment using validated code
  - JPL 91 Solar Proton Model
  - Specify total fluence spectrum over lifetime [particles/cm^2]
- Simulate radiation exposure of detector using radiation transport code
  - Displacement Damage Dose (DDD)
  - Total Ionizing Dose (TID)

Radiation Code Comparison

Solar Proton Code Cross Check

- Predictions of solar protons at L2 for WFIRST and JWST were compared
- WFIRST (JPL model at 6 yrs)
- JWST (GSFC model scaled to 6 yrs)

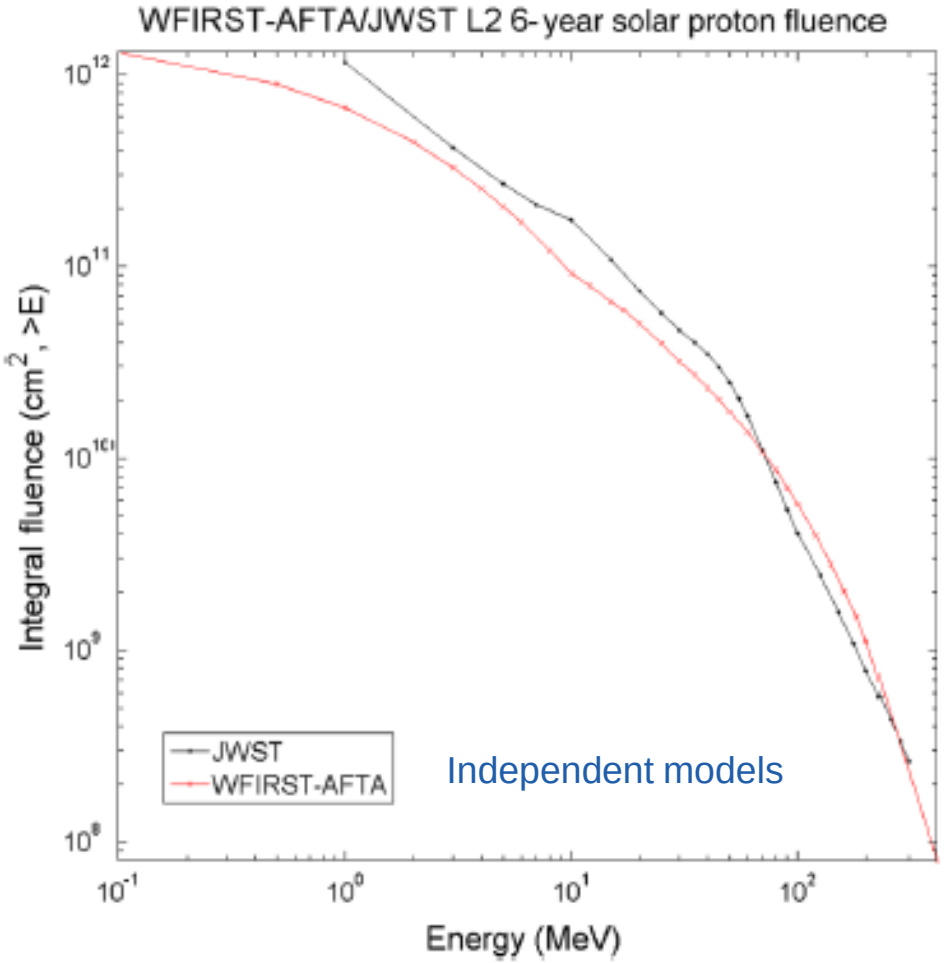


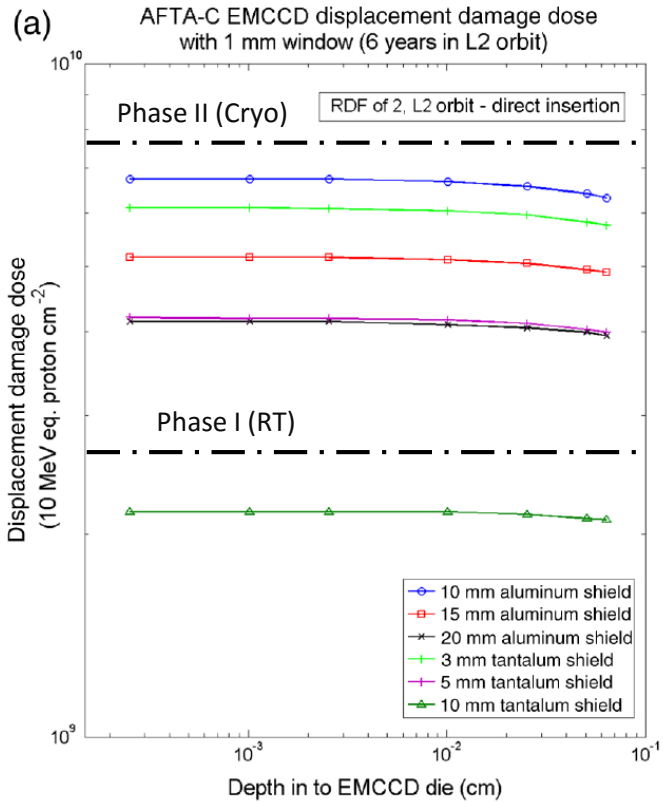
Fig. 4 Comparison of independent predictions for the solar proton fluence in a direct insertion L2 orbit for the WFIRST and JWST missions. WFIRST data were calculated based on the JPL 91 Solar Proton model at a 95% confidence level and with a radiation design factor (RDF) = 2. JWST data were scaled to 6 years based on 5-year data taken from "The Radiation Environment for the JWST" (JWST-RPT-000453).[35]

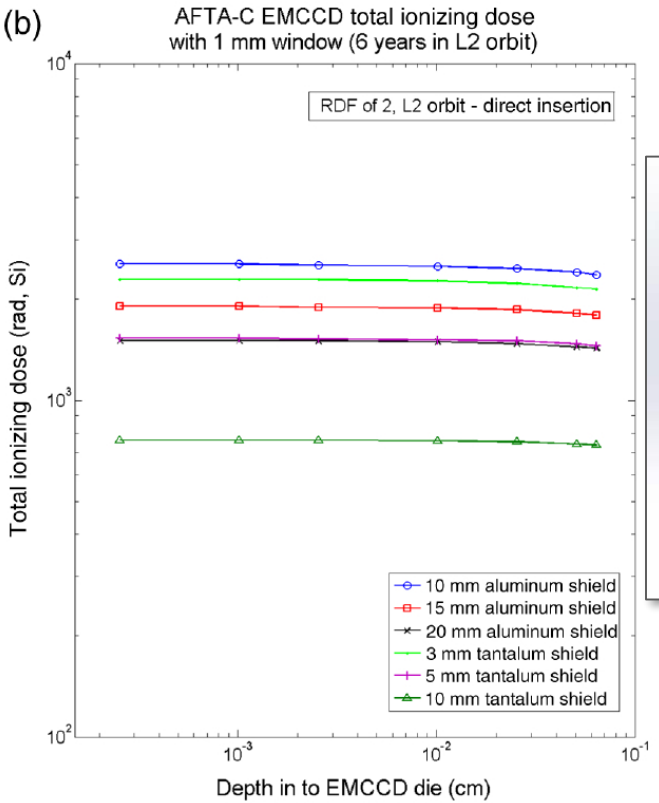
Summary of Radiation Analysis

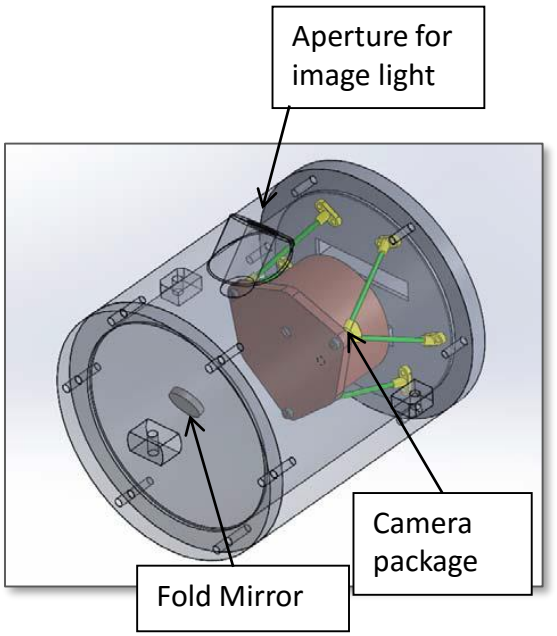
Radiation transport code NOVICE used to predict DDD and TID in L2

- Direct insertion orbit, i.e. trajectory through Earth's trapped-particle rad belts is inconsequential
  - Soar proton model run at 95% confidence level
  - Code was run for a range of camera shielding materials/thicknesses to in form choice of maximum test exposure
  - Performance after mission life exposure was used to optimize shielding material/thickness
- Code predicted cumulative TID of only 1 krad with 1 mm glass window
  - => DDD is the major hazard

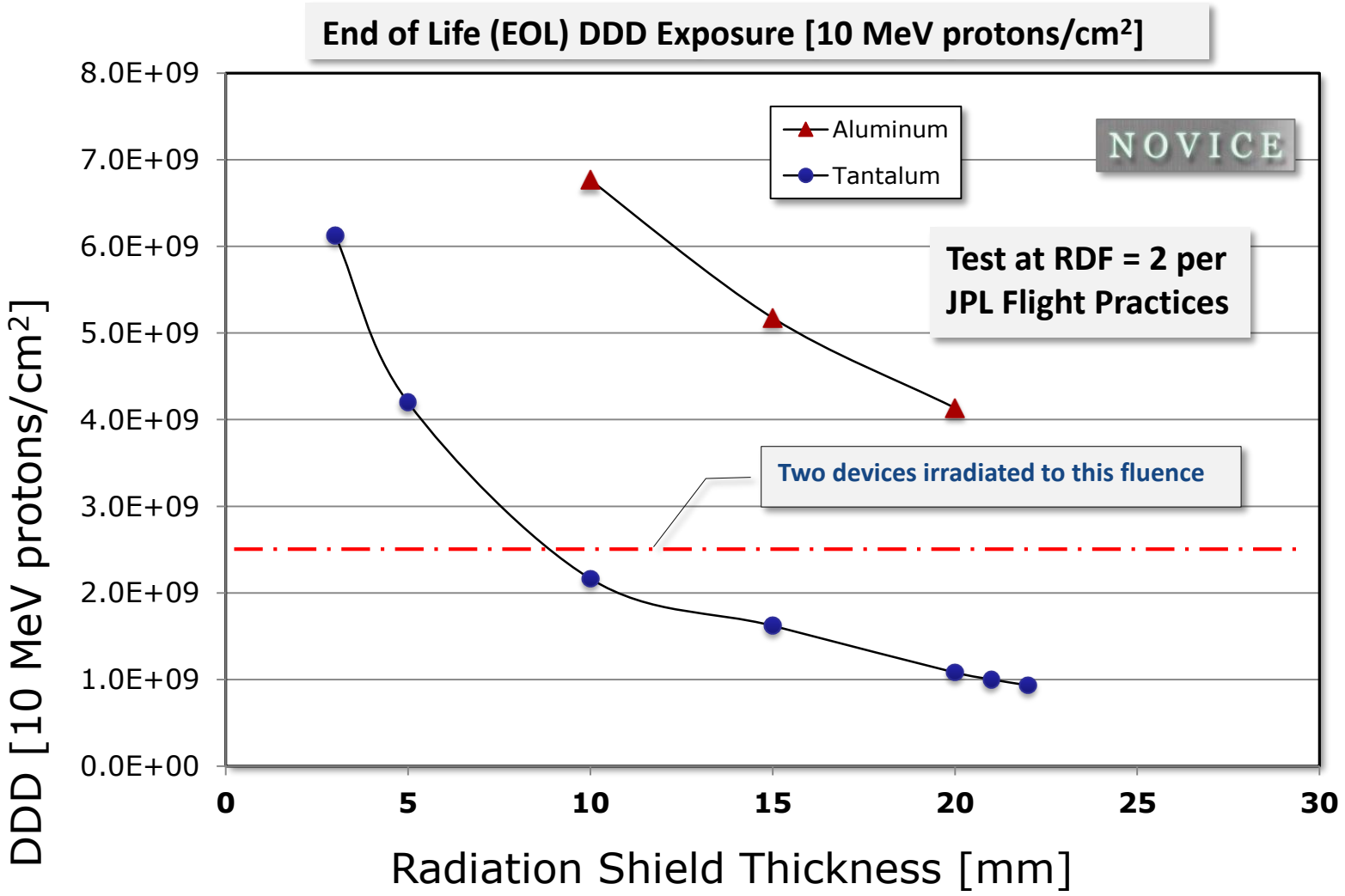
Harding & Demers, et al. (2016)







Limits of Shielding



Data from analysis by Michael Cherng *JPL Internal Memo 5132-15-015*, 18 March 2015 & recent results July 2016