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Date	:	March 4, 1997
From	:	H. Evans
To	:	J. Cornelisse (PF)
cc.	:	E. Daly (WMA) PF QCA WMA

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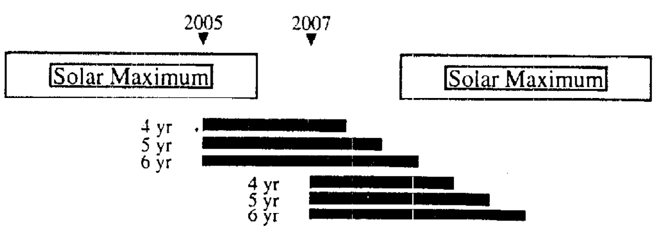
FIRST L-2 Radiation Environment

Attached are plots characterising the radiation environment to be encountered by the Far Infra Red and Submillimetre Telescope (FIRST) mission at the L-2 Lagrangian libration point. Only trapped particle and solar flare protons are considered; galactic cosmic rays have been ignored in this analysis. Dose-depth curves through aluminium shielding for a spherical shell geometry and solar cell degradation curves for silicon and gallium arsenide cells are provided.

Two mission start dates (2005 and 2007) and three mission durations (4, 5 and 6 years) are considered. The next period of solar maximum activity, where the majority of damaging solar particles are produced, is expected to commence in mid 1999 and last approximately 7 years. Thus the 6 year mission starting in 2005 will include the end of one solar maximum



period and the start of the next.The 4 and 5 year missions that begin in 2005 will end during the period of solar minimum activity, resulting in an identical exposure to solar protons and hence have been treated as a single case.

The trapped radiation models employed were those developed by Vette and colleagues [1] for NASA before the mid 70's (AE8 and AP8 for electrons and protons respectively). These models were used to provide an orbit averaged particle spectra for half a GTO orbit after mapping the satellite orbit into geomagnetic coordinates through the Jenson and Cain 1960 geomagnetic field model and the Cain et. al 120-term 1966 IGRF geomagnetic field model projected to 1970. The half GTO orbit is an approximation to the final insertion trajectory provided by Ariane V, differences in the actual insertion trajectory may produce different results. However, given the dominance of the solar proton contribution to the radiation environment the overall results should not vary significantly.

The solar flare proton model used was that recently developed by Feynman et al. at JPL [2]. This model uses a data set spanning 3 solar cycles, and is replacing the older King model [3] as the standard solar flare model used by spacecraft engineers.

These mission averaged spectra were then used to calculate the dose deposition as a function of aluminium shielding thickness using the SHIELDOSE [4] code for the slab shield geometry and spherical shell geometry. These spectra are also used to calculate damage equivalent fluences of 1 MeV electrons as a function of cover glass thickness with the EQFRUX code [5]. Infinite cell backshielding is assumed and a 10 MeV proton to 1 MeV electron equivalence ration of 3000 is used for maximum power degradation. The infinite backshielding implies that the incident flux is from one side of the solar cell, consistent with the cells being mounted on the body of the spacecraft. To include back incident radiation, as is expected on solar panels, the 1 MeV electron fluence for a coverglass thickness that is equivalent to the shielding provided by the substrate should be added to the front irradiation figure. This should only be done for the electron component and the proton component for the I_{SC} fluences and only serves as a first approximation.

References

1. J.I. Vette, "Trapped radiation models in Development of Improved Models of the Earth's Radiation Environment", Technical Note 1 (Chapter 4), 1989.
2. J. Feynman, T.P. Armstrong, L. Dao-Gibner, and S. Silverman, "New Interplanetary Proton Fluence Model", *J. Spacecraft*, 27, 403, 1990.
3. J.H. King, "Solar Proton Fluences for 1977-1983 Space Missions", J. Spacecraft, 11, 401, 1974.
4. S.M. Seltzer, "SHIELDOSE: a computer code for space shielding radiation dose calculations", TN-1116 (NBS), 1980.
5. H.Y. Tada, J.R. Carter, "Solar Cell Radiation Handbook", JPL, 1982.

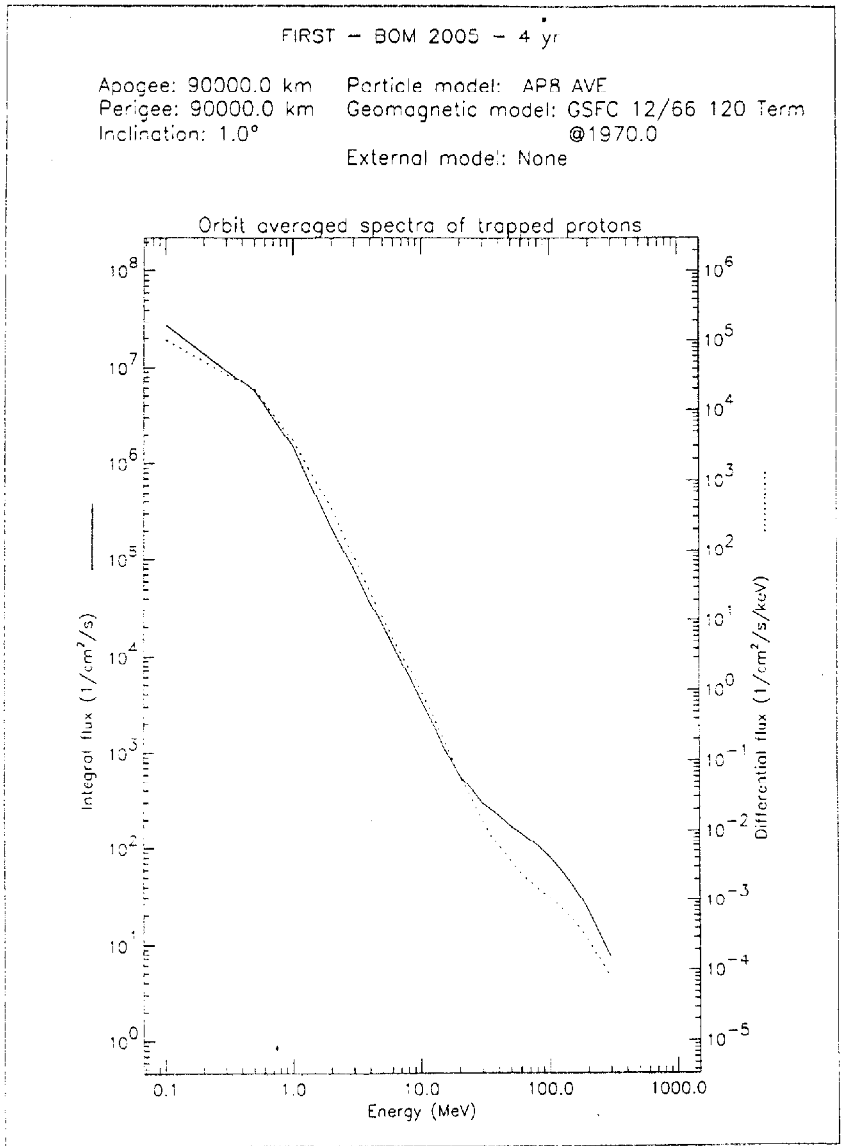


Figure 1. The orbit averaged trapped proton fluence for half of a GTO orbit. This should serve as an approximation to the environment for the Ariane V insertion trajectory.

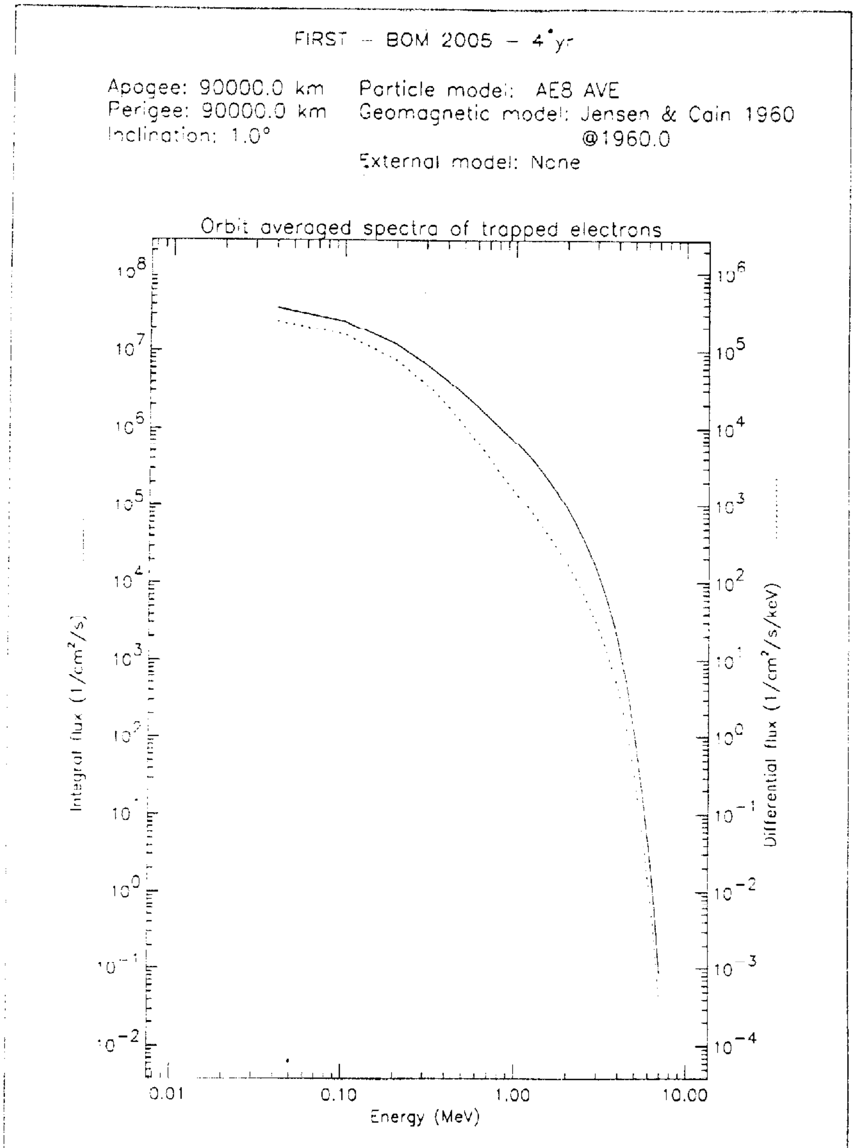


Figure 2. The orbit averaged trapped electron fluence for half of a GTO orbit. This should serve as an approximation to the environment for the Ariane V insertion trajectory.

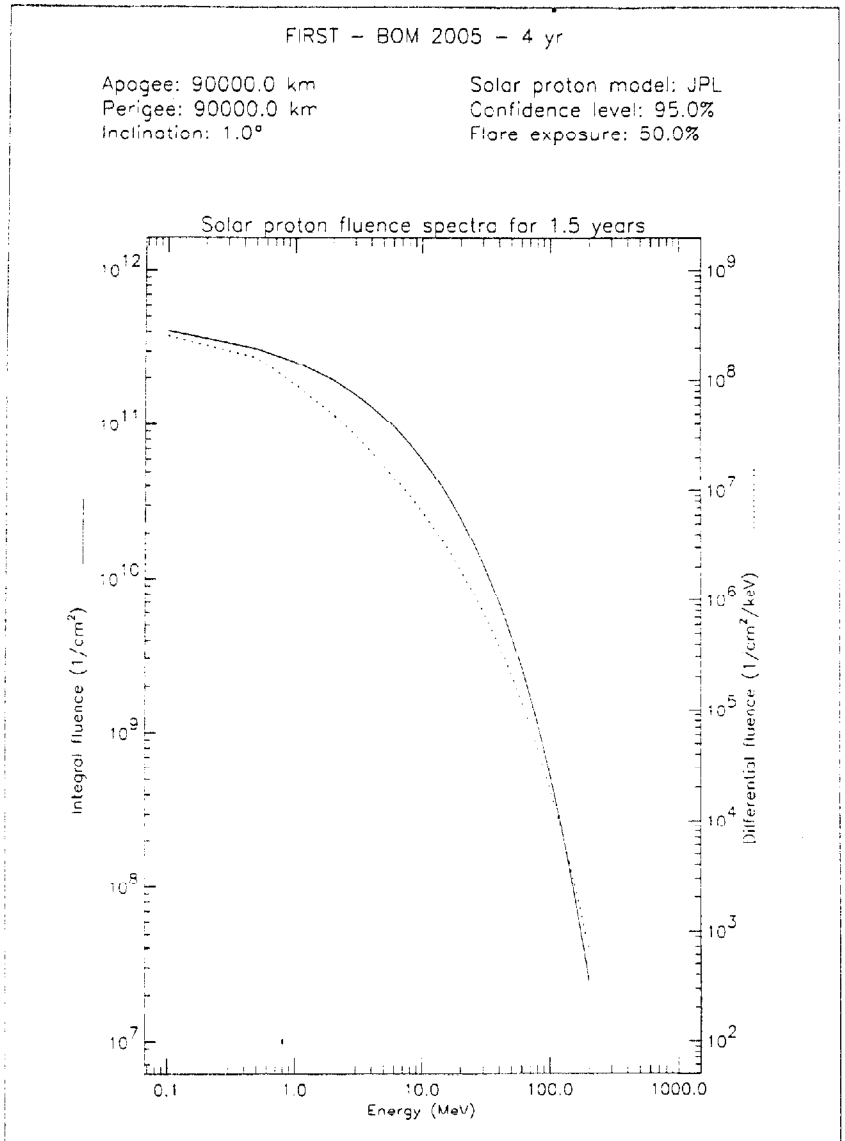


Figure 3. Solar proton fluence spectrum for the 4 and 5 year mission that commences in 2005.

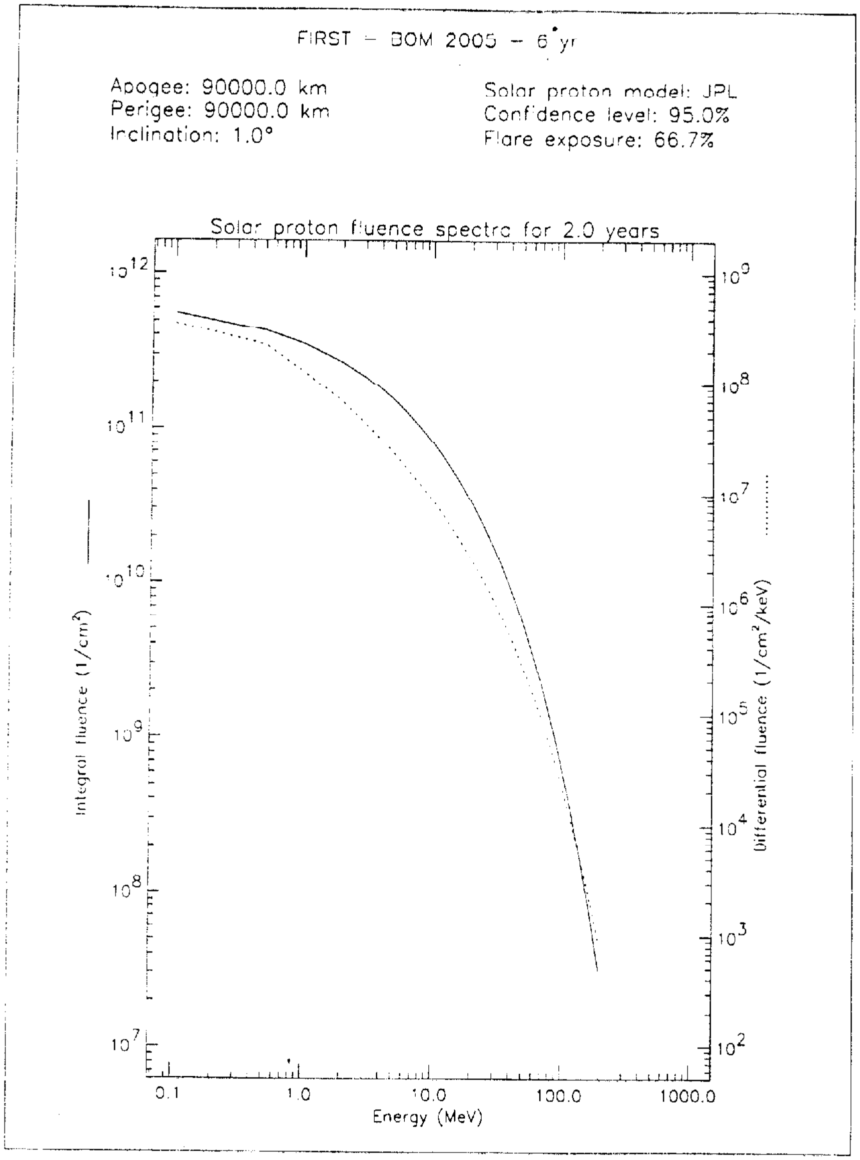


Figure 4. Solar proton fluence spectrum for the 6 year mission that commences in 2005.

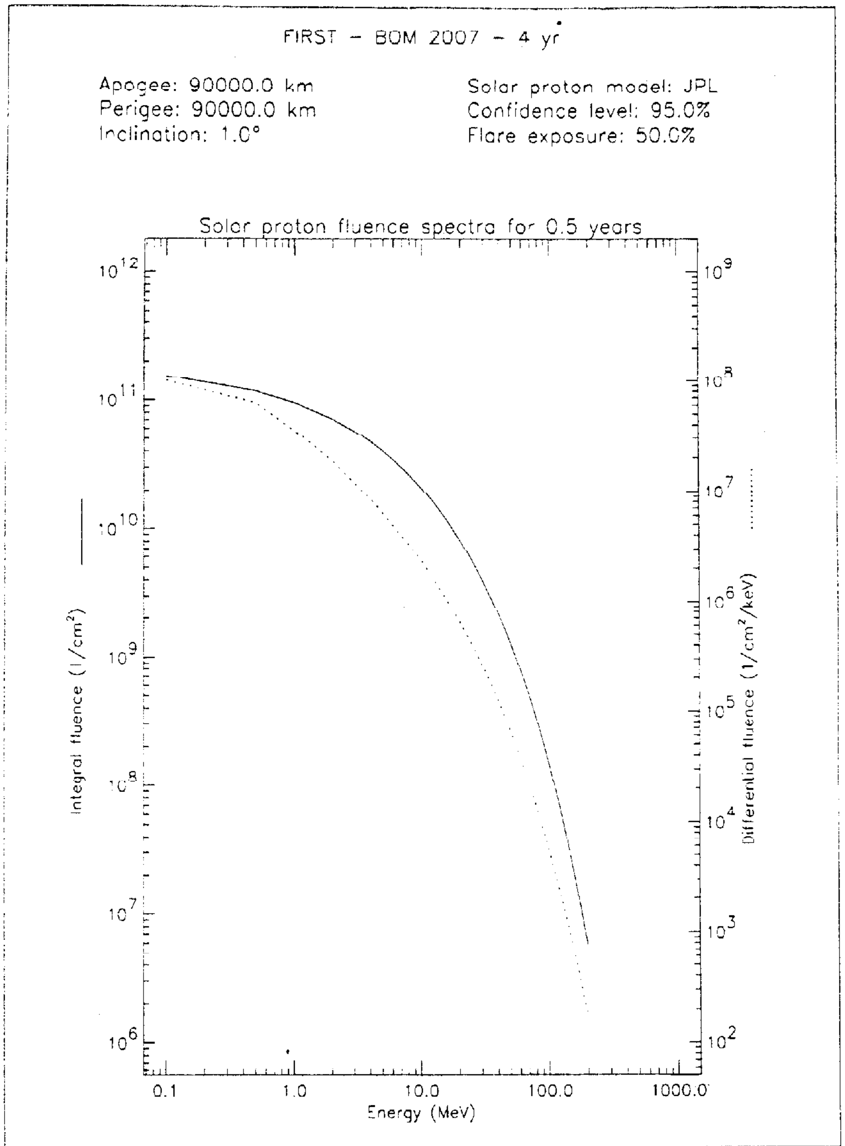


Figure 5. Solar proton fluence spectrum for the 4 year mission that commences in 2007.

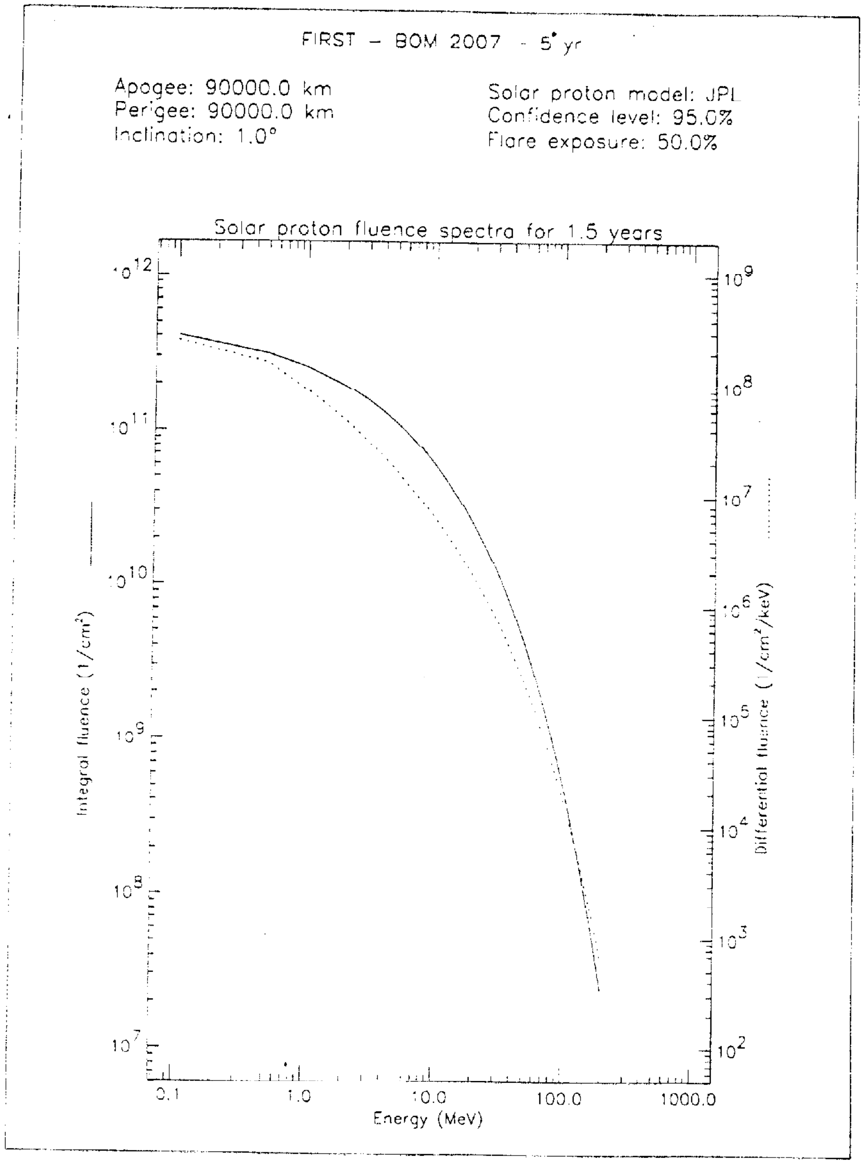


Figure 6. Solar proton fluence spectrum for the 5 year mission that commences in 2007.

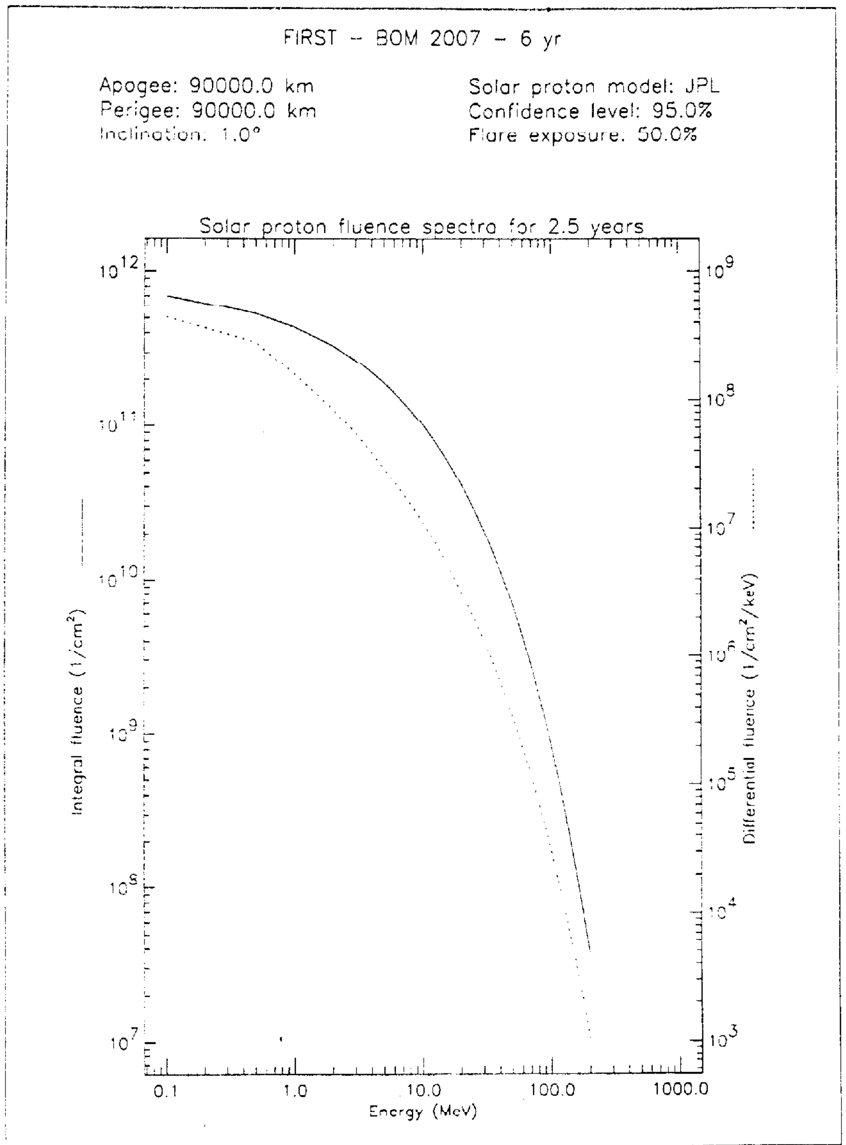


Figure 7. Solar proton fluence spectrum for the 6 year mission that commences in 2007.

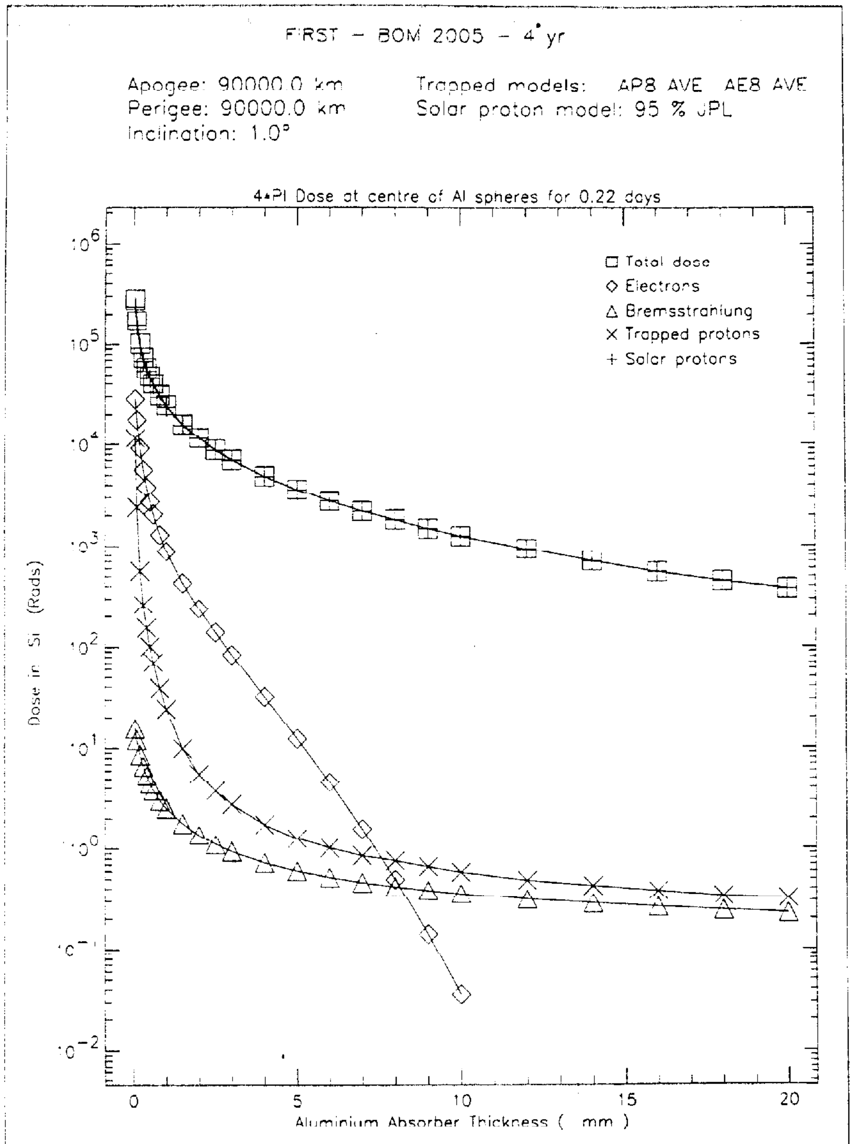


Figure 8. Radiation dose in silicon as a function of aluminium spherical shielding thickness for the four and five year mission commencing in 2005. This includes the trapped particle dose from the Ariane V injection trajectory.

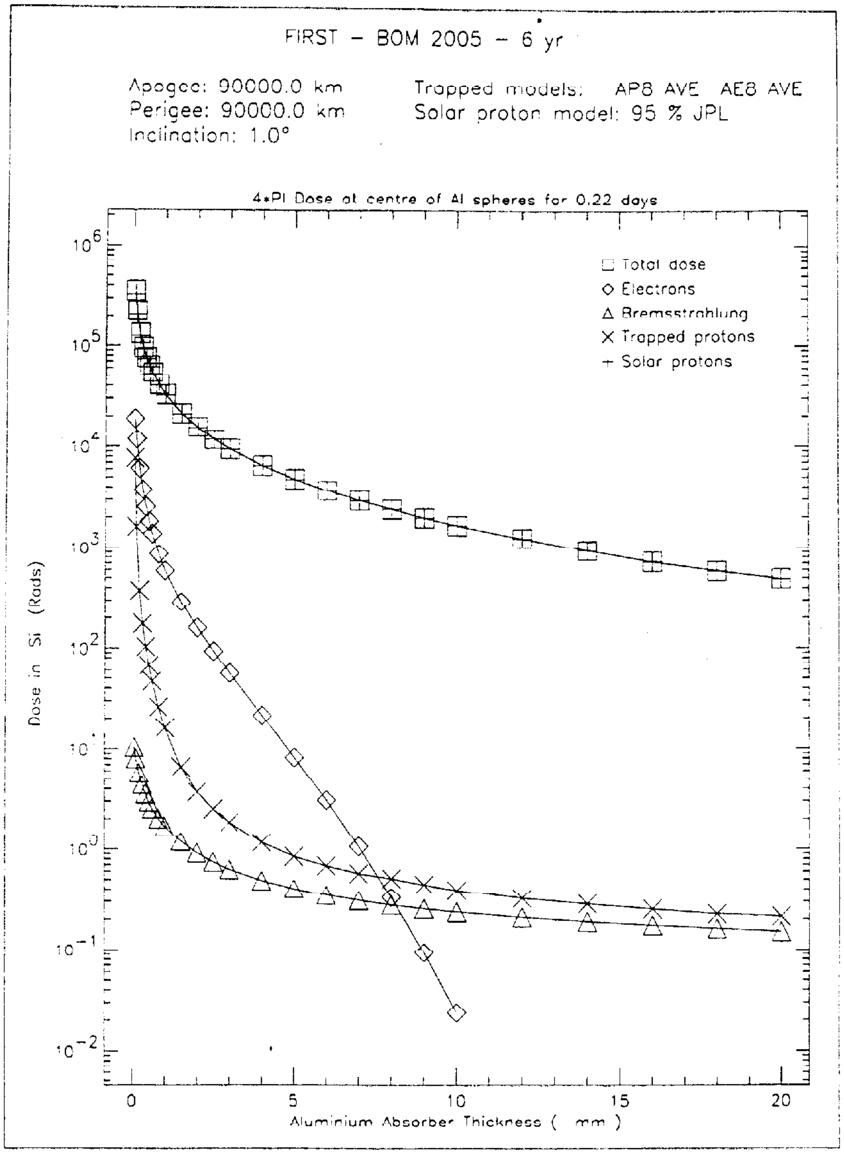


Figure 9. Radiation dose in silicon as a function of aluminium spherical shielding thickness for the six year mission commencing in 2005. This includes the trapped particle dose from the Ariane V injection trajectory.

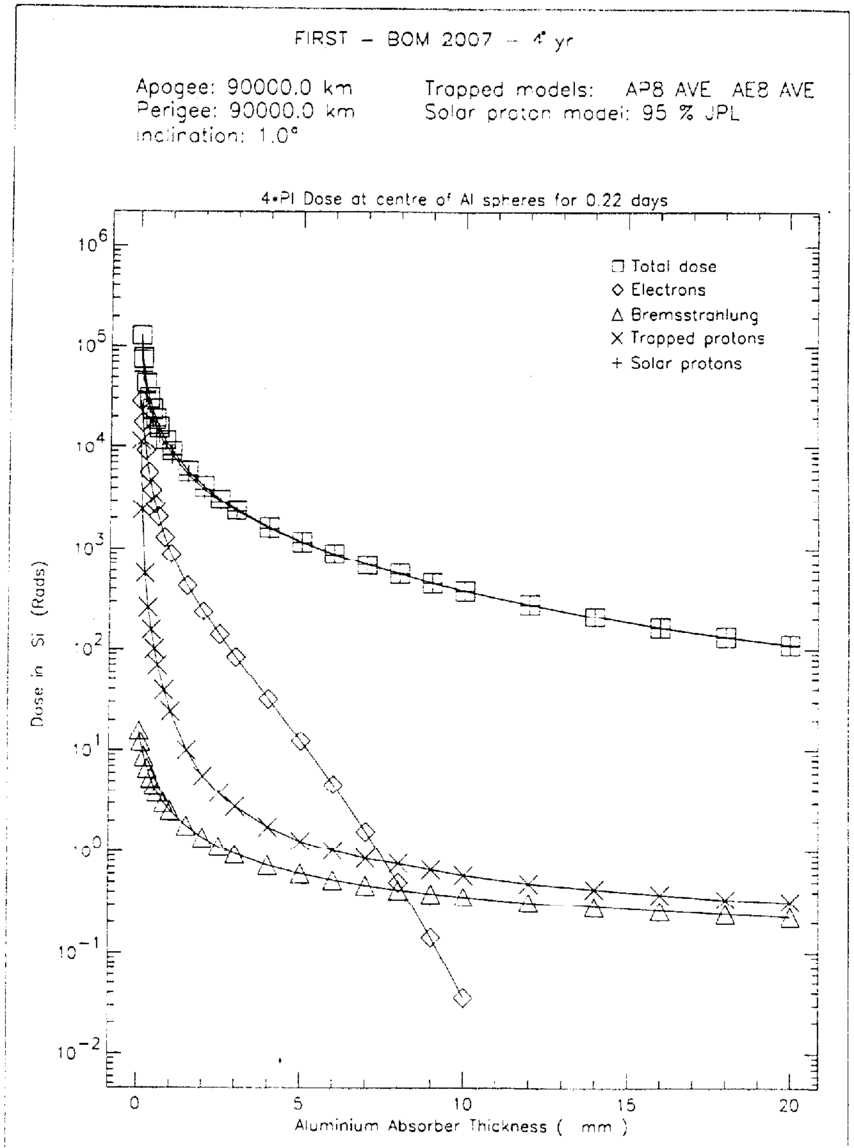


Figure 10. Radiation dose in silicon as a function of aluminium spherical shielding thickness for the four year mission commencing in 2007. This includes the trapped particle dose from the Ariane V injection trajectory.

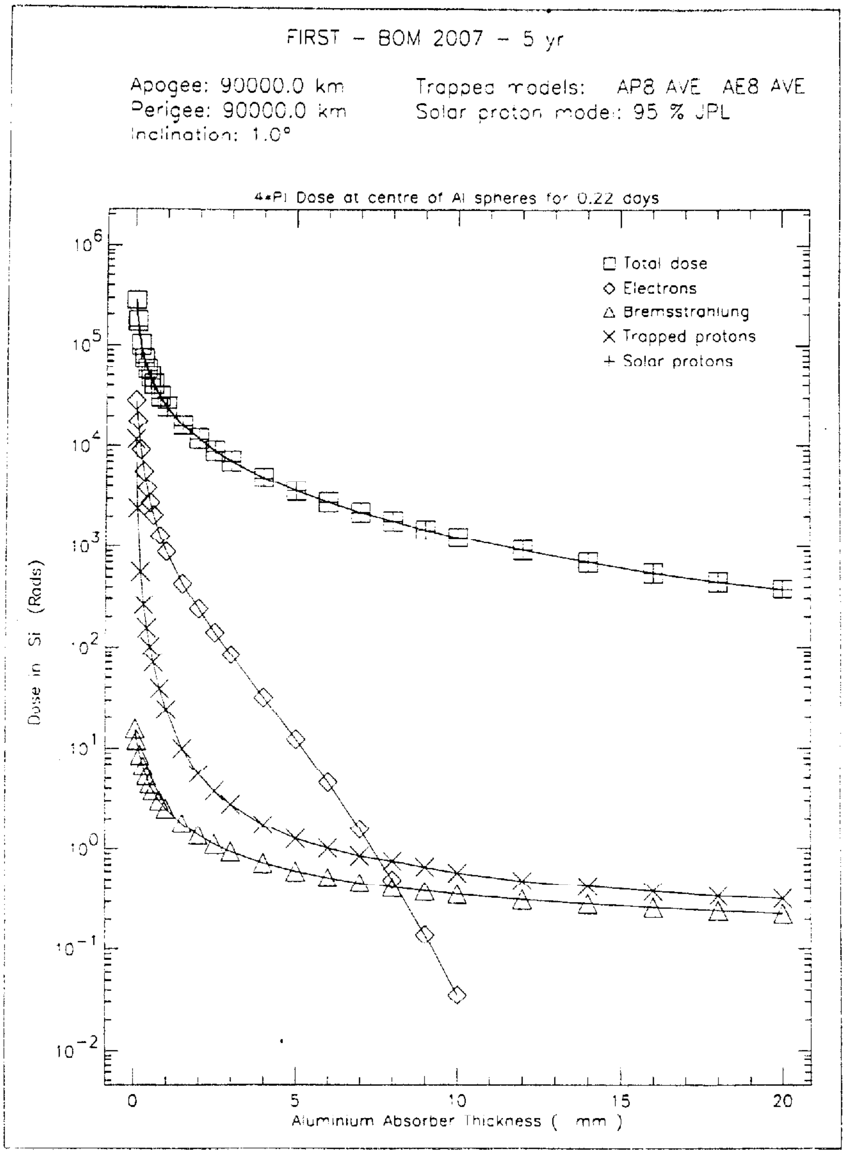


Figure 11. Radiation dose in silicon as a function of aluminium spherical shielding thickness for the five year mission commencing in 2007. This includes the trapped particle dose from the Ariane V injection trajectory.

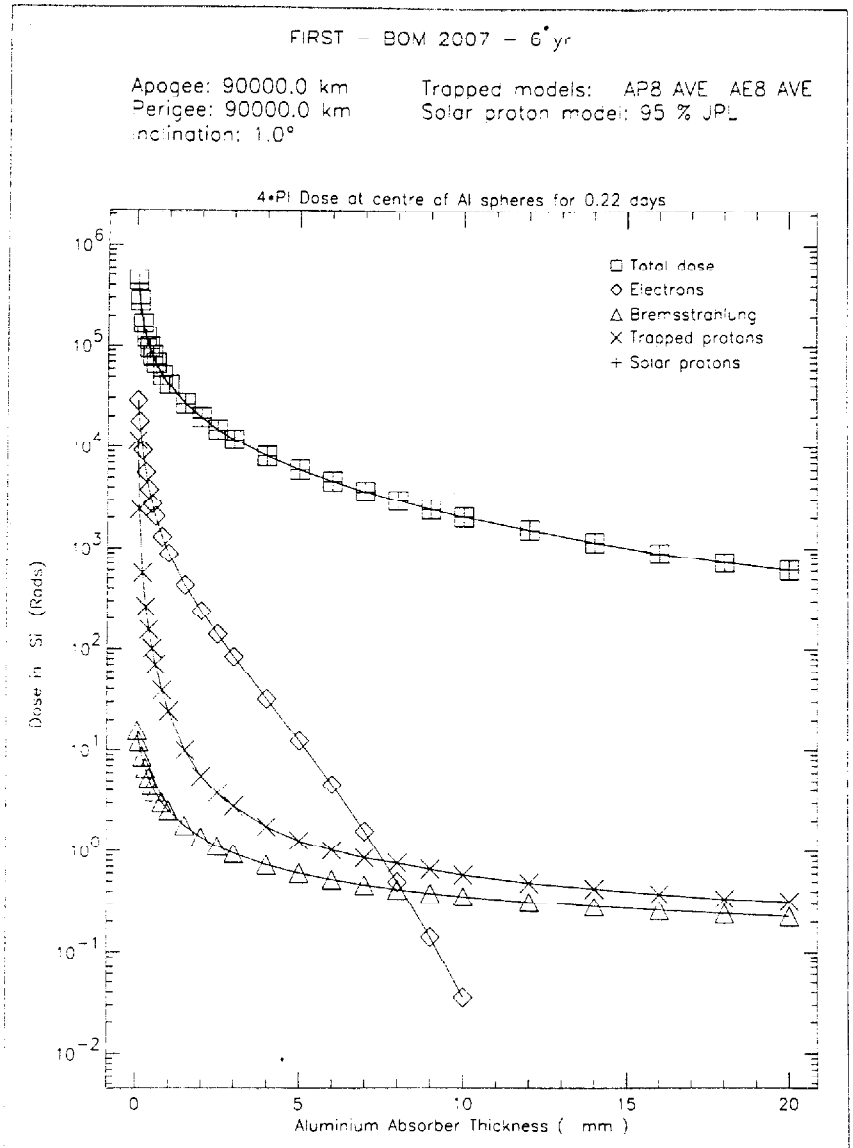


Figure 12. Radiation dose in silicon as a function of aluminium spherical shielding thickness for the six year mission commencing in 2007. This includes the trapped particle dose from the Ariane V injection trajectory.

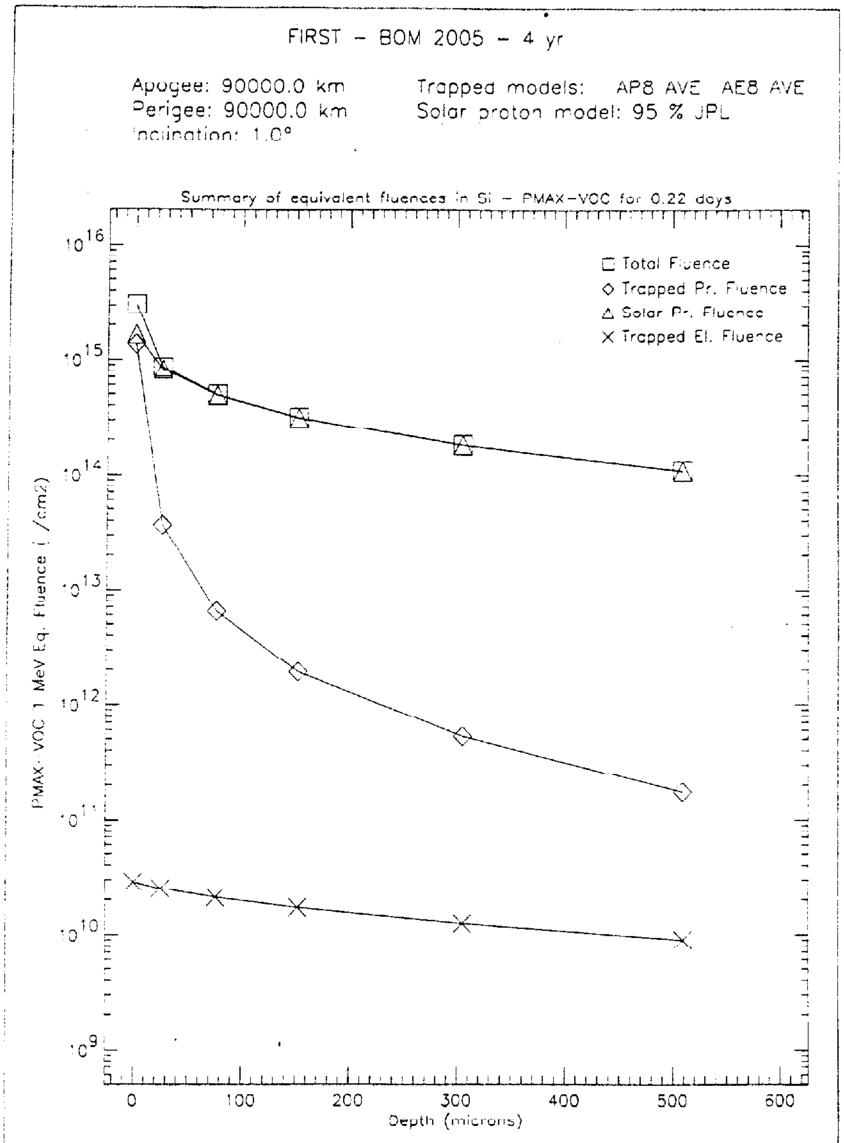


Figure 13. Equivalent silicon 1 MeV P_{MAX}-V_{OC} electron fluence for the four and five year missions commencing in 2005. This includes the trapped particle contribution from the Ariane V injection trajectory.

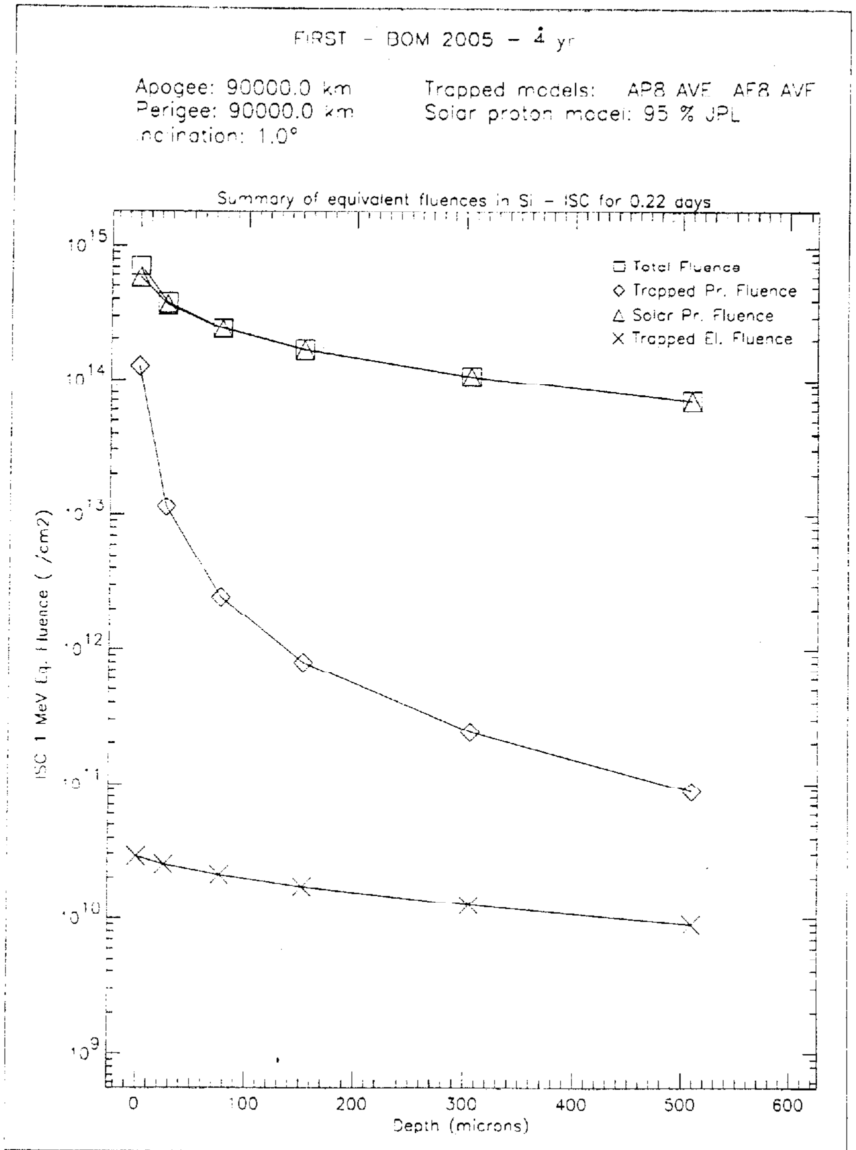


Figure 14. Equivalent silicon 1 MeV I_{SC} electron fluence for the four and five year missions commencing in 2005. This includes the trapped particle contribution from the Ariane V injection trajectory.

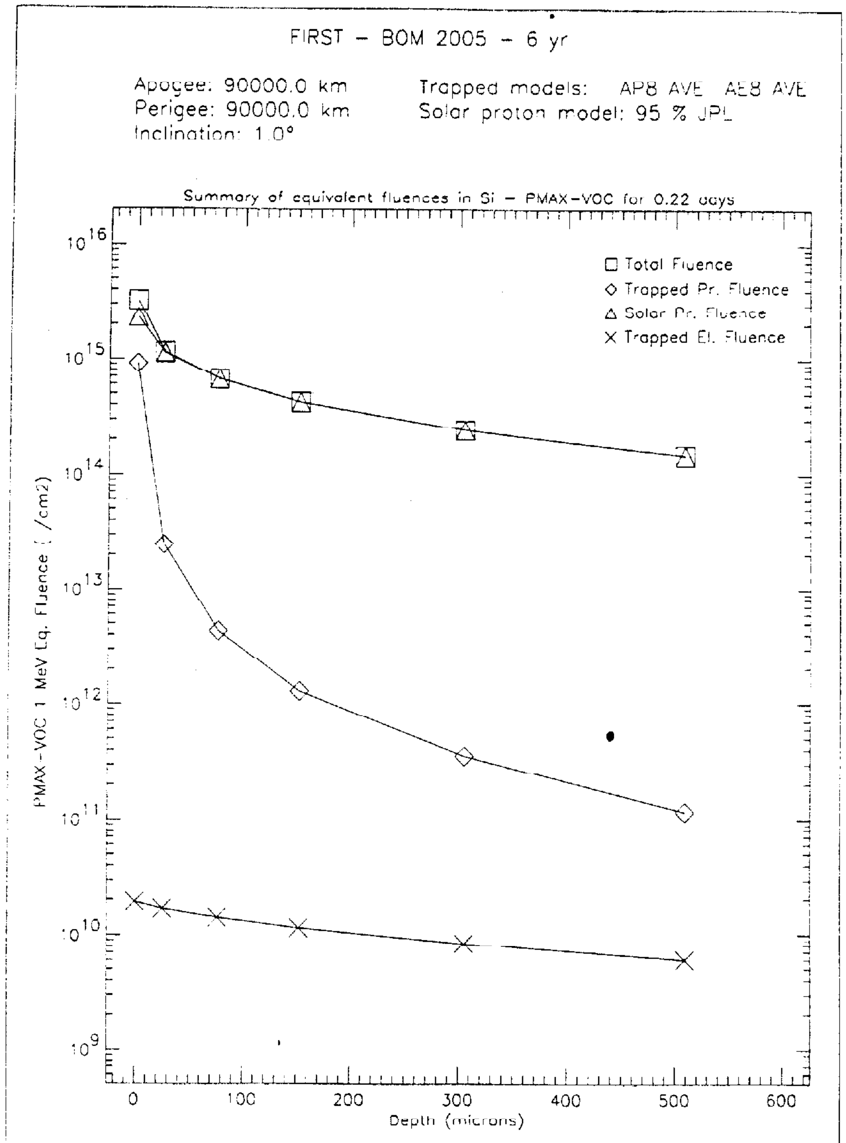


Figure 15. Equivalent silicon 1 MeV P_{MAX}-V_{OC} electron fluence for the six year mission commencing in 2005. This includes the trapped particle contribution from the Ariane V injection trajectory.

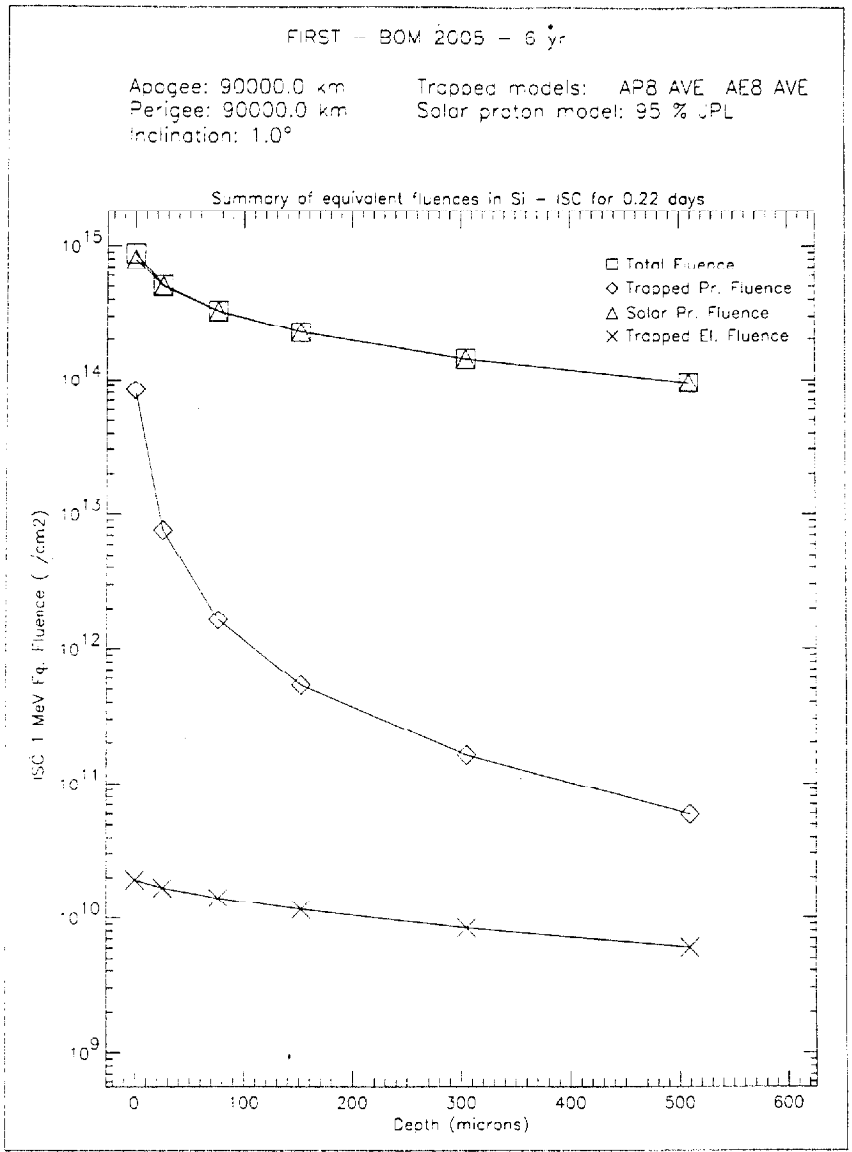


Figure 16. Equivalent silicon 1 MeV I_{SC} electron fluence for the six year mission commencing in 2005. This includes the trapped particle contribution from the Ariane V injection trajectory.

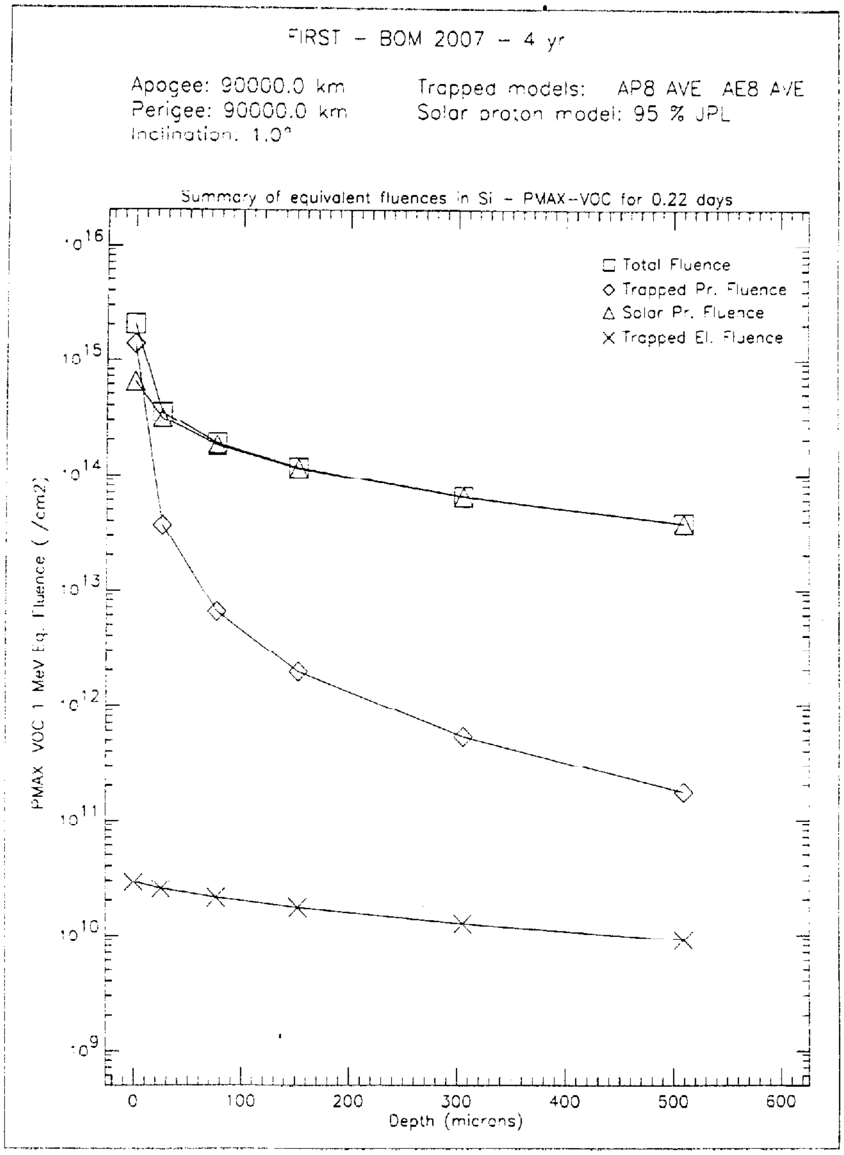


Figure 17. Equivalent silicon 1 MeV P_{MAX}-V_{OC} electron fluence for the four year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.

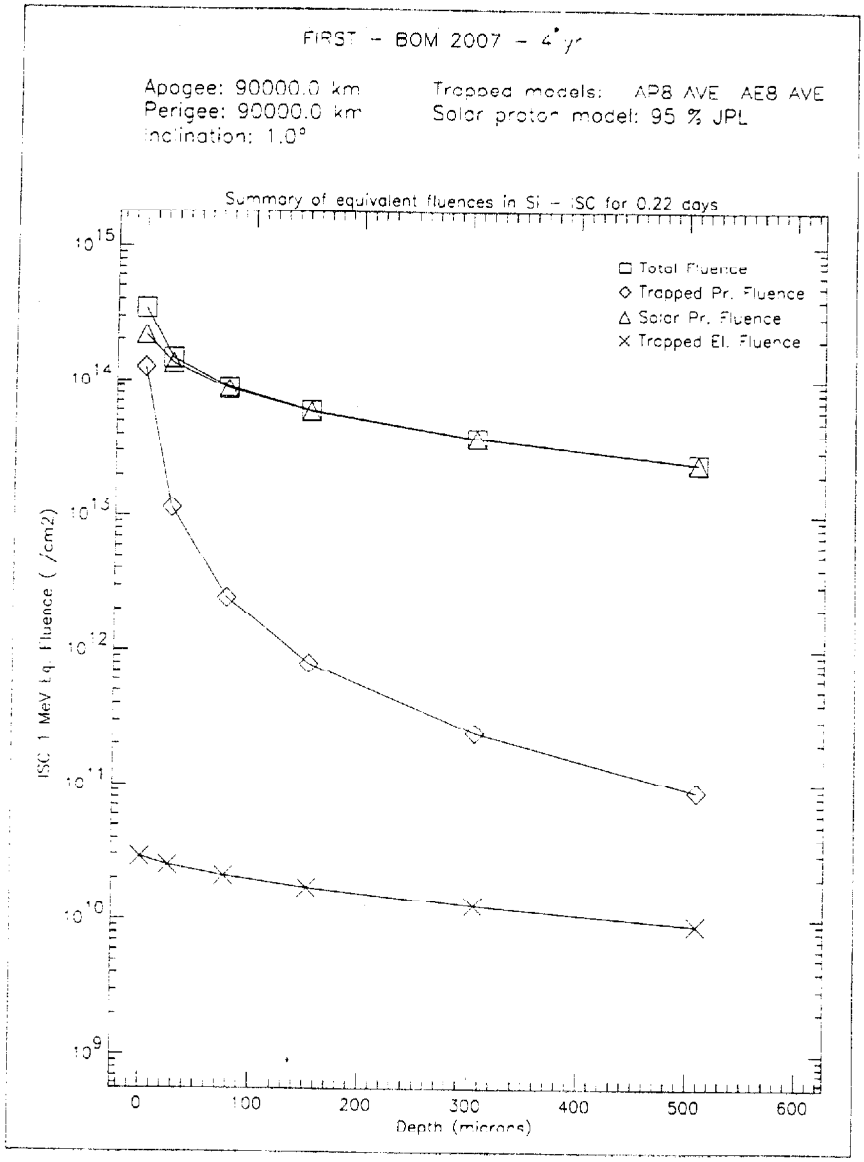


Figure 18. Equivalent silicon 1 MeV I_{SC} electron fluence for the four year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.

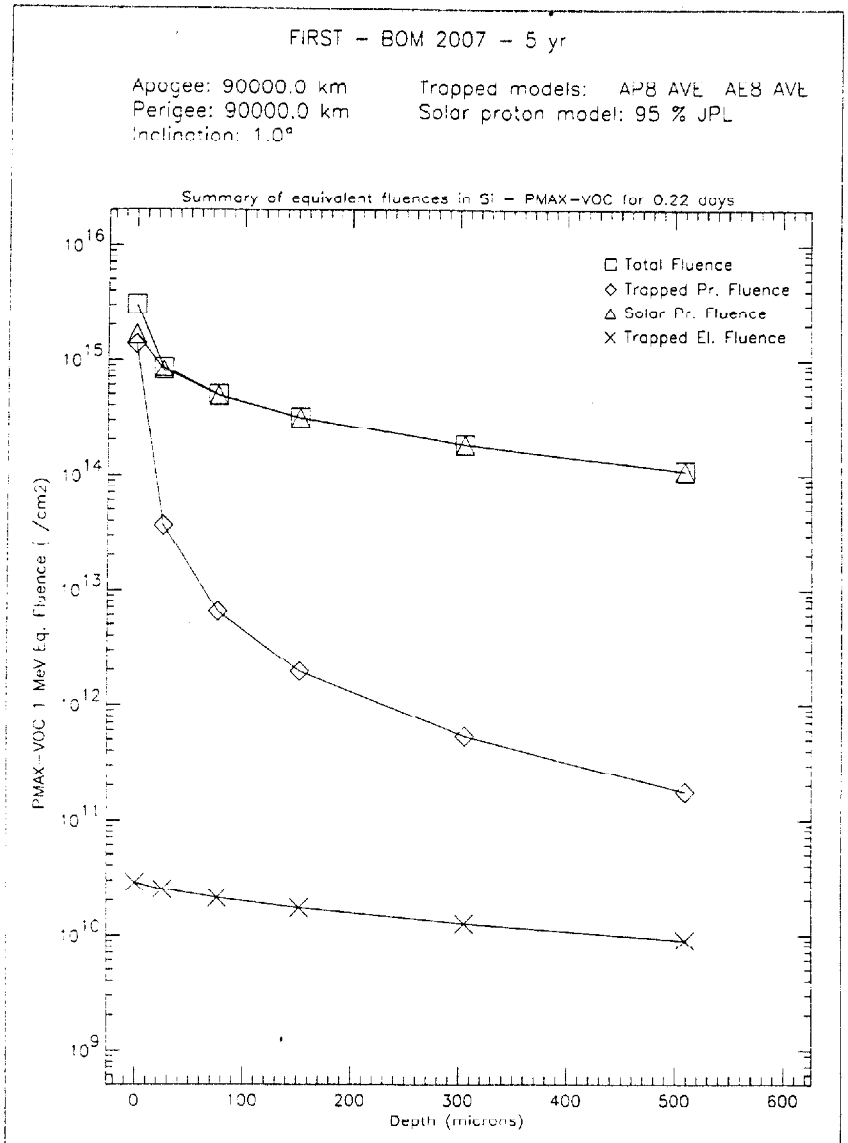


Figure 19. Equivalent silicon 1 MeV P_{MAX}-V_{OC} electron fluence for the five year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.

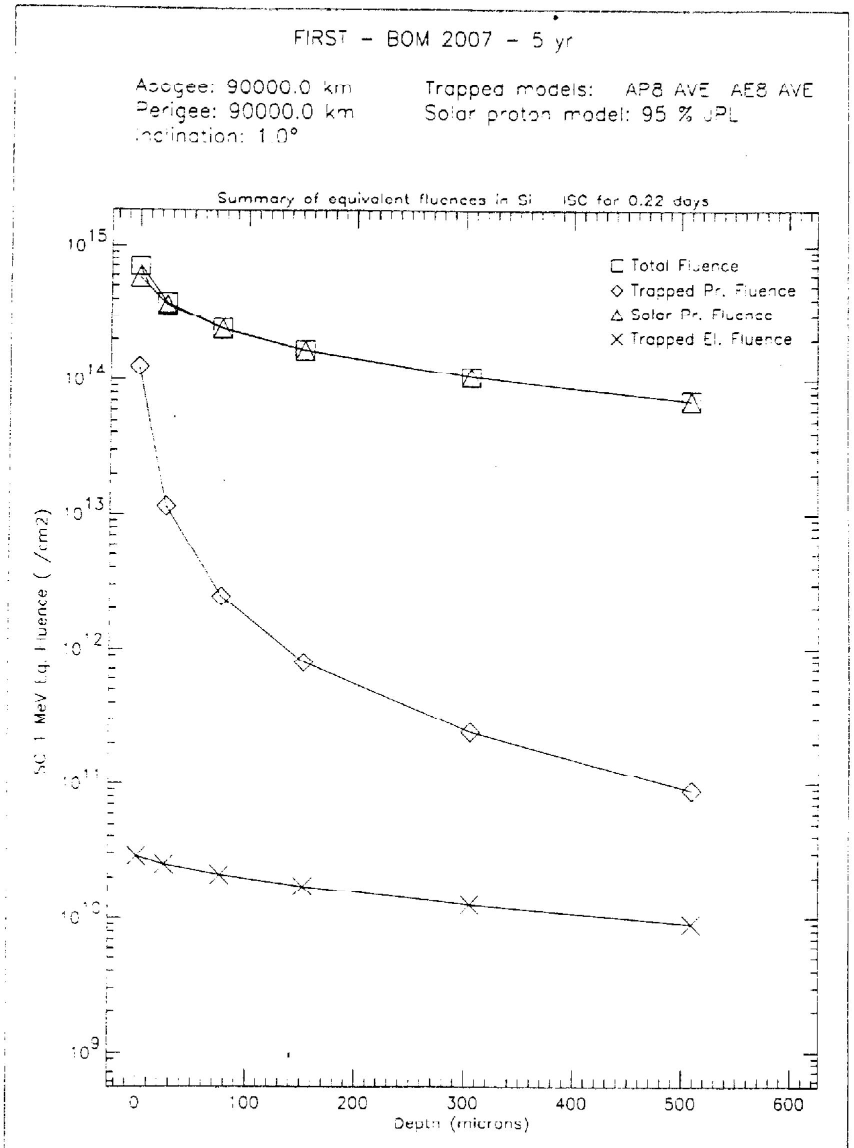


Figure 20. Equivalent silicon 1 MeV I_{SC} electron fluence for the five year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.

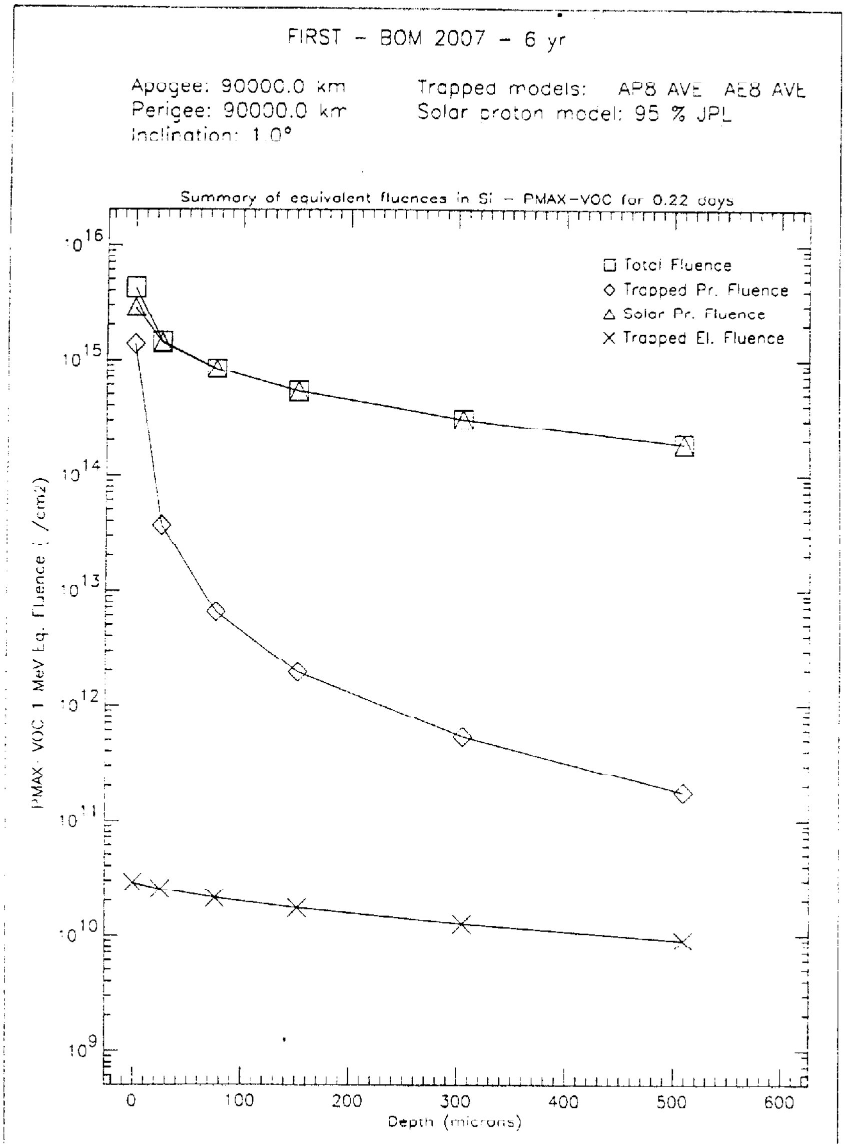


Figure 21. Equivalent silicon 1 MeV P_{MAX}-V_{OC} electron fluence for the six year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.

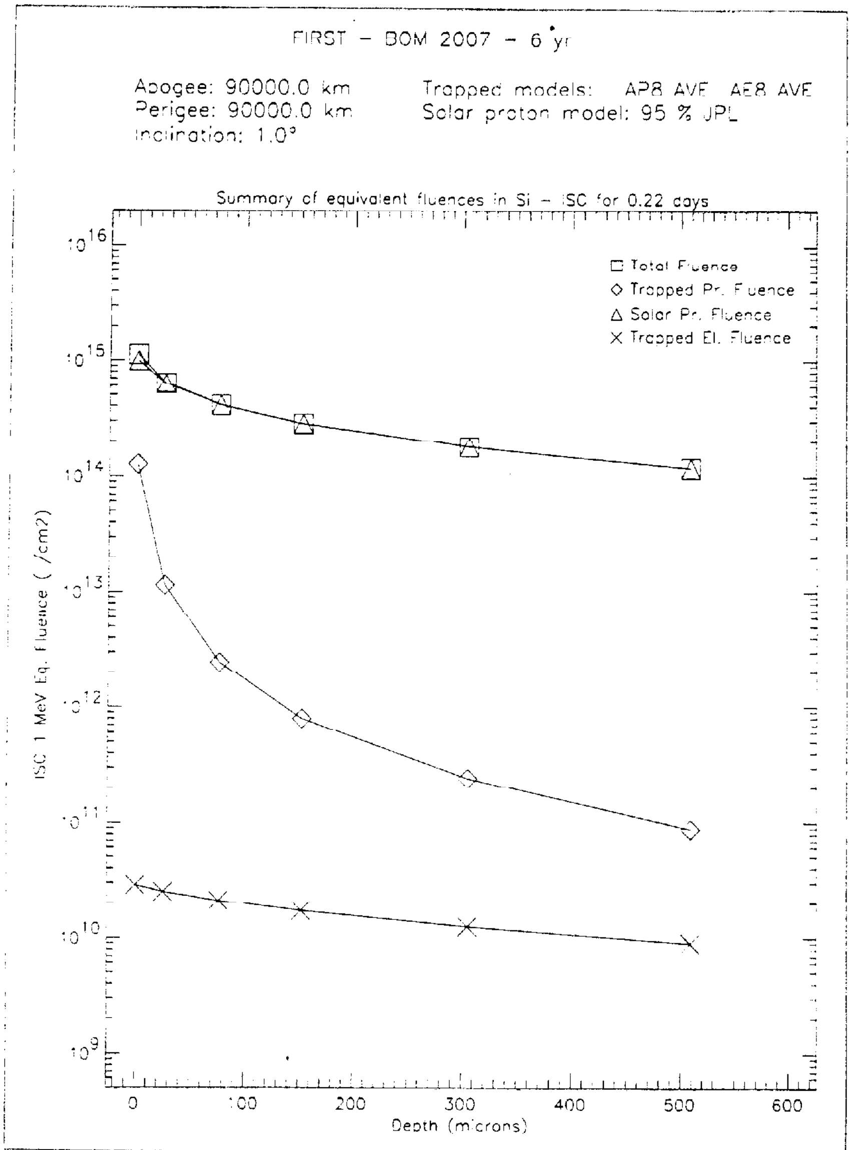


Figure 22. Equivalent silicon 1 MeV I_{SC} electron fluence for the six year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.

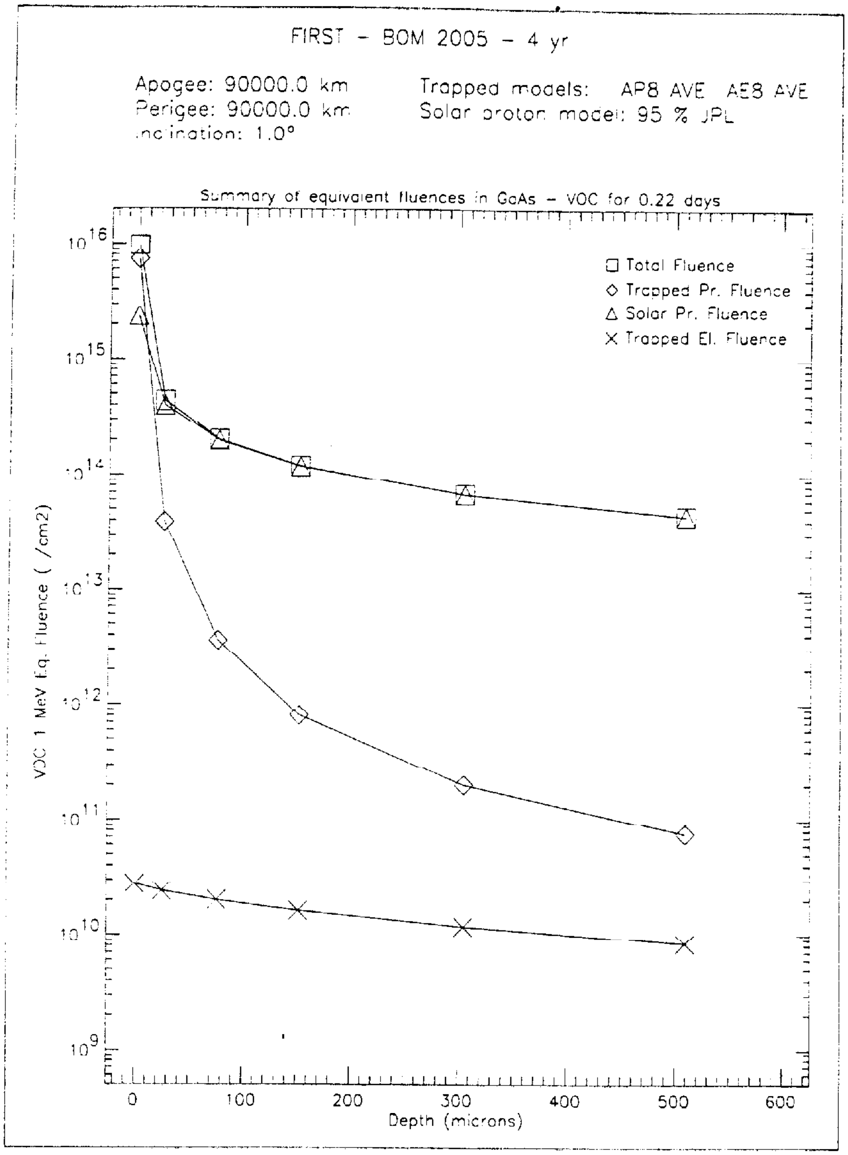


Figure 23. Equivalent Gallium Arsenide 1 MeV V_{OC} electron fluence for the four and five year missions commencing in 2005. This includes the trapped particle contribution from the Ariane V injection trajectory.

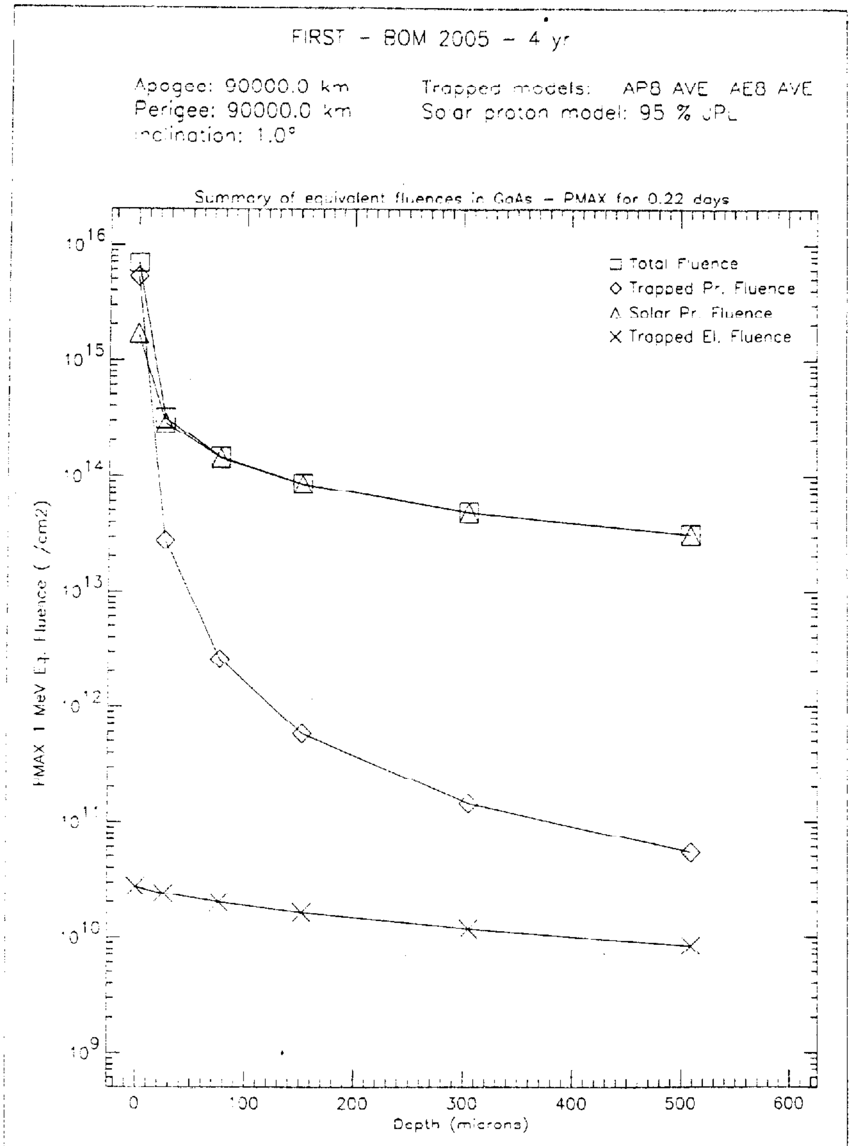


Figure 24. Equivalent Gallium Arsenide 1 MeV P_{MAX} electron fluence for the four and five year missions commencing in 2005. This includes the trapped particle contribution from the Ariane V injection trajectory.

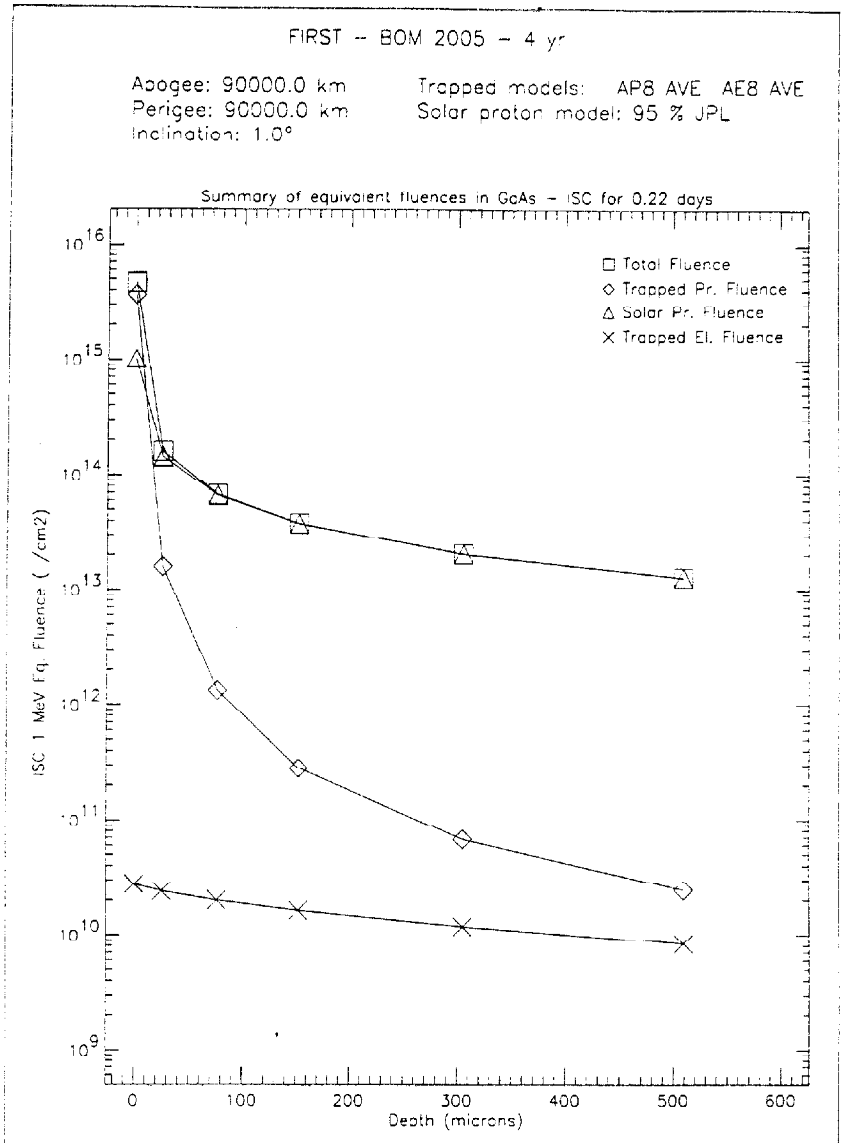


Figure 25. Equivalent Gallium Arsenide 1 MeV I_{SC} electron fluence for the four and five year missions commencing in 2005. This includes the trapped particle contribution from the Ariane V injection trajectory.

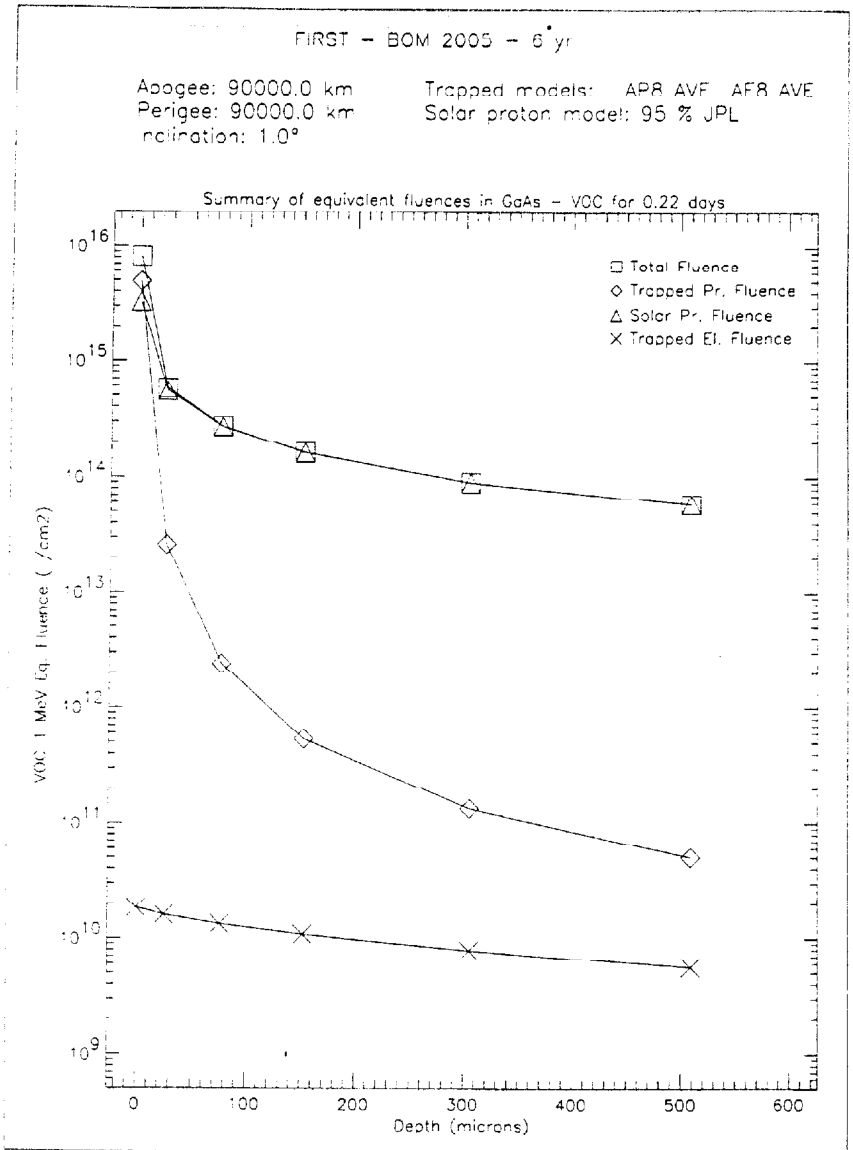


Figure 26. Equivalent Gallium Arsenide 1 MeV V_{OC} electron fluence for the six year mission commencing in 2005. This includes the trapped particle contribution from the Ariane V injection trajectory.

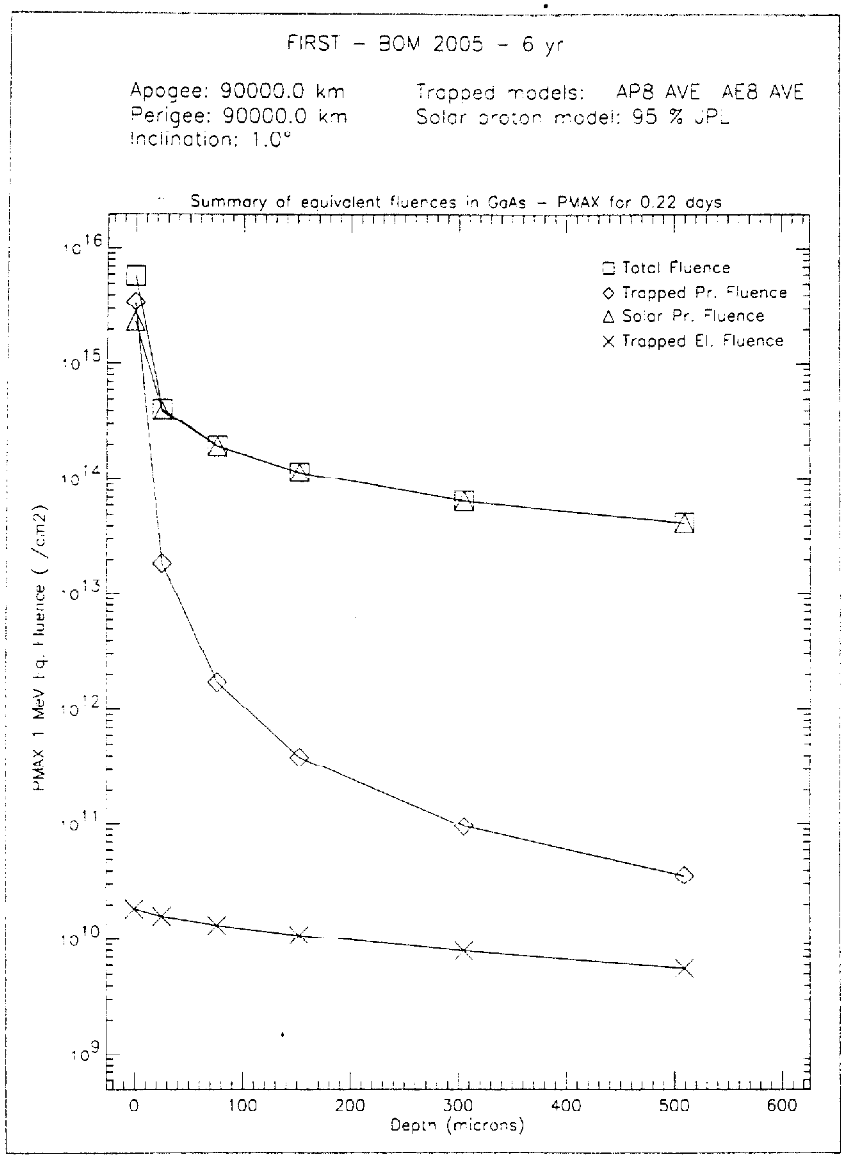


Figure 27. Equivalent Gallium Arsenide 1 MeV P_{MAX} electron fluence for the six year mission commencing in 2005. This includes the trapped particle contribution from the Ariane V injection trajectory.

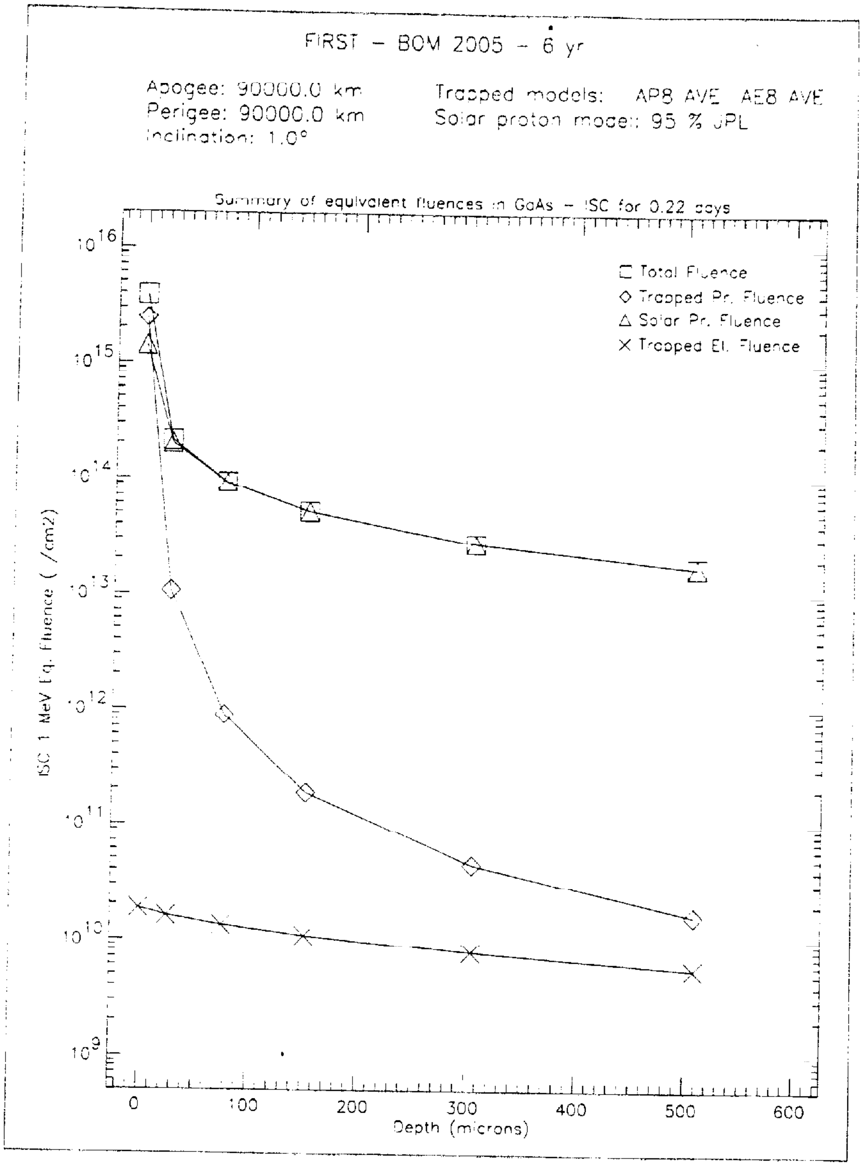


Figure 28. Equivalent Gallium Arsenide 1 MeV I_{SC} electron fluence for the six year mission commencing in 2005. This includes the trapped particle contribution from the Ariane V injection trajectory.

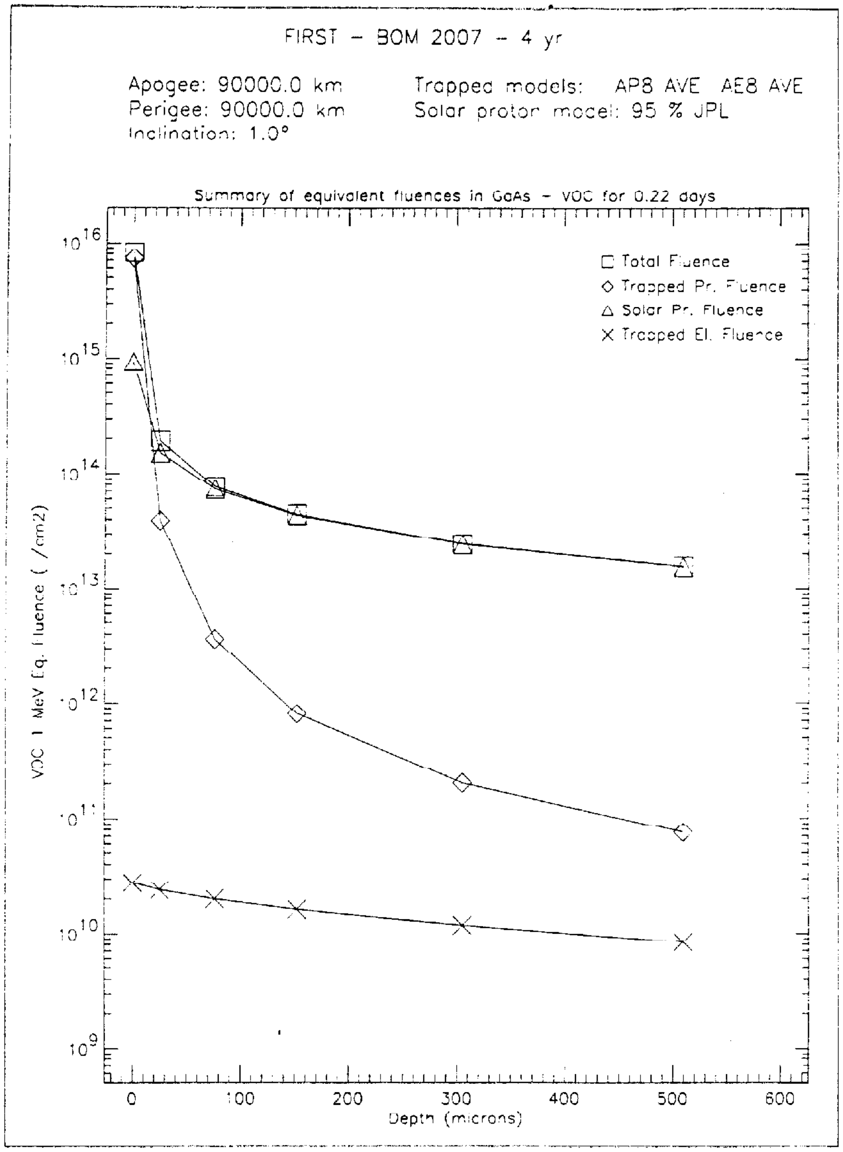


Figure 29. Equivalent Gallium Arsenide 1 MeV V_{OC} electron fluence for the four year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.

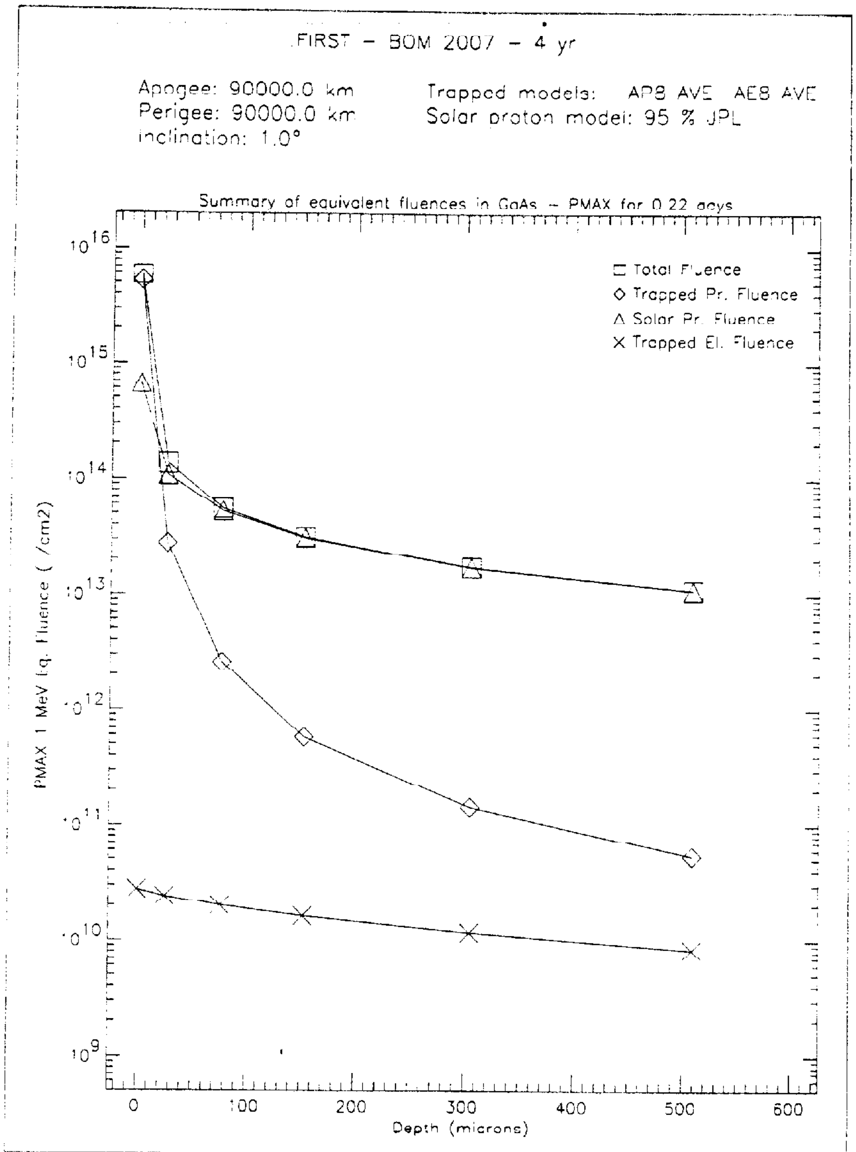


Figure 30. Equivalent Gallium Arsenide 1 MeV P_{MAX} electron fluence for the four year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.

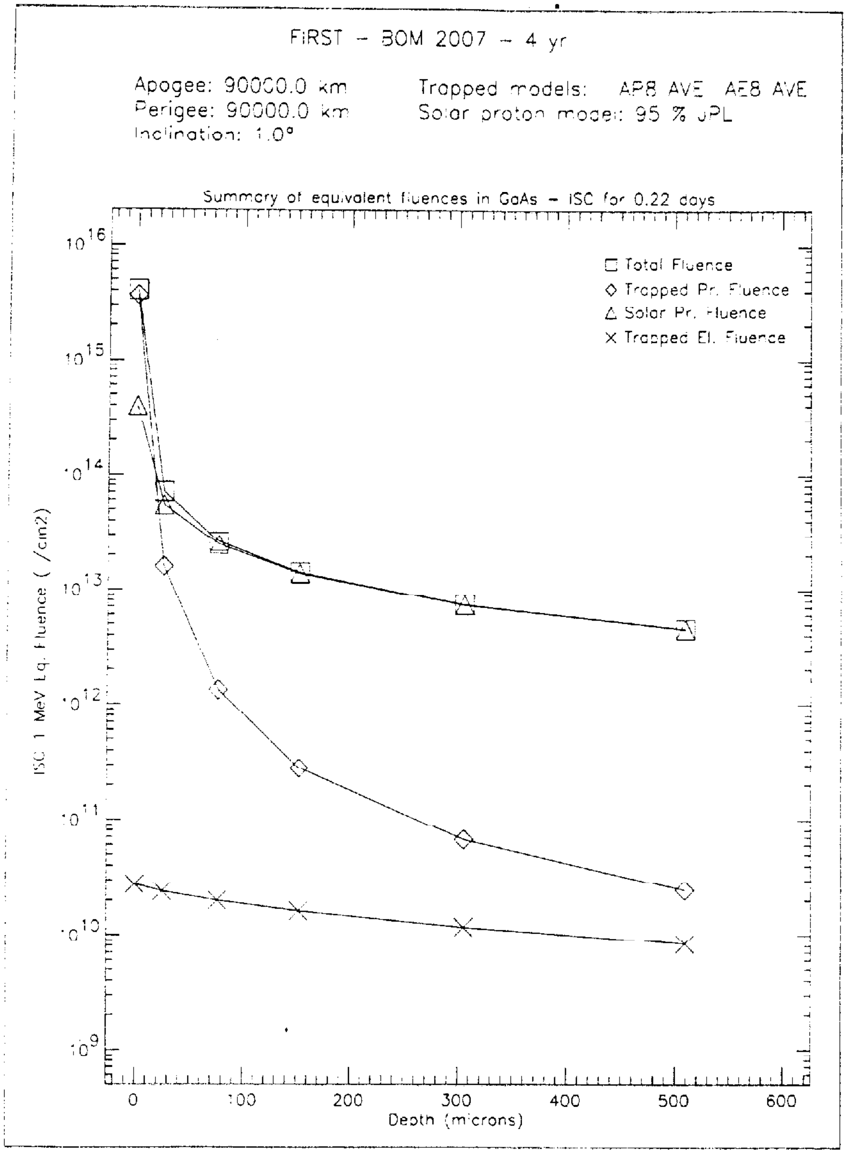


Figure 31. Equivalent Gallium Arsenide 1 MeV I_{SC} electron fluence for the four year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.

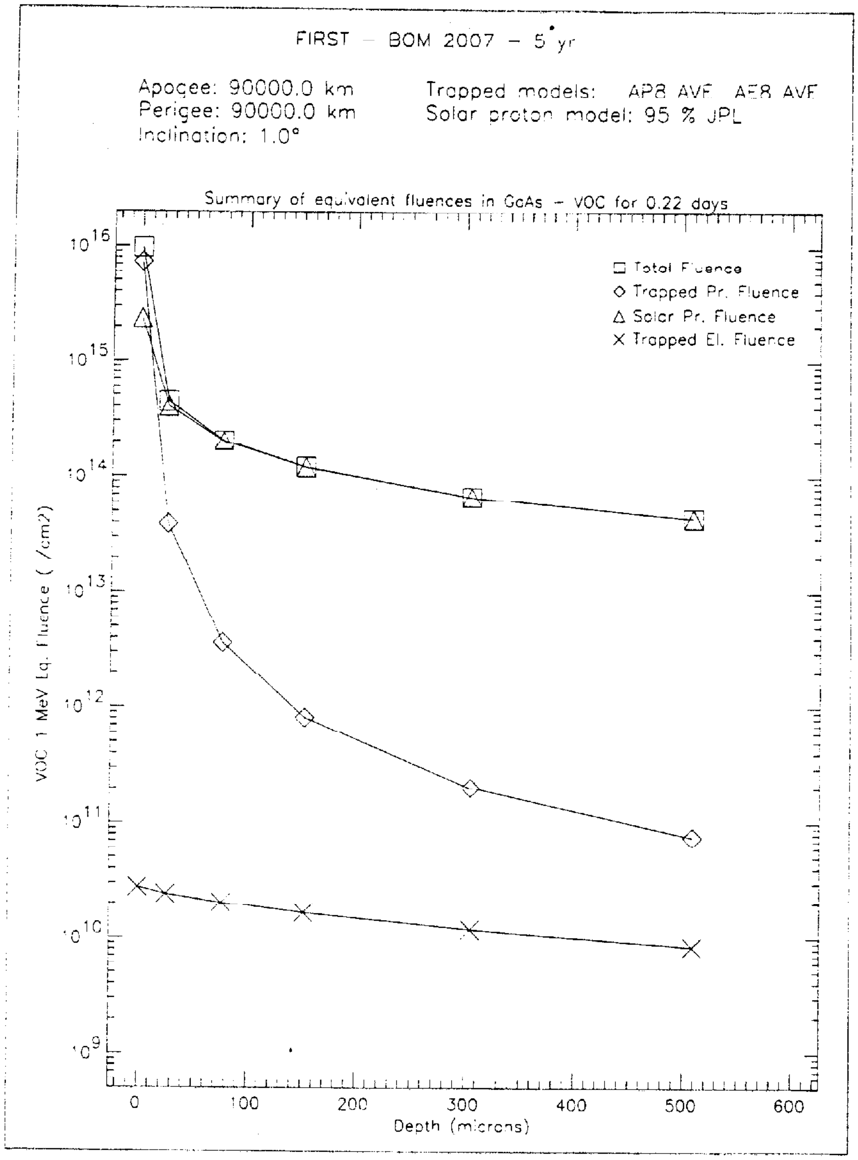


Figure 32. Equivalent Gallium Arsenide 1 MeV V_{OC} electron fluence for the five year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.

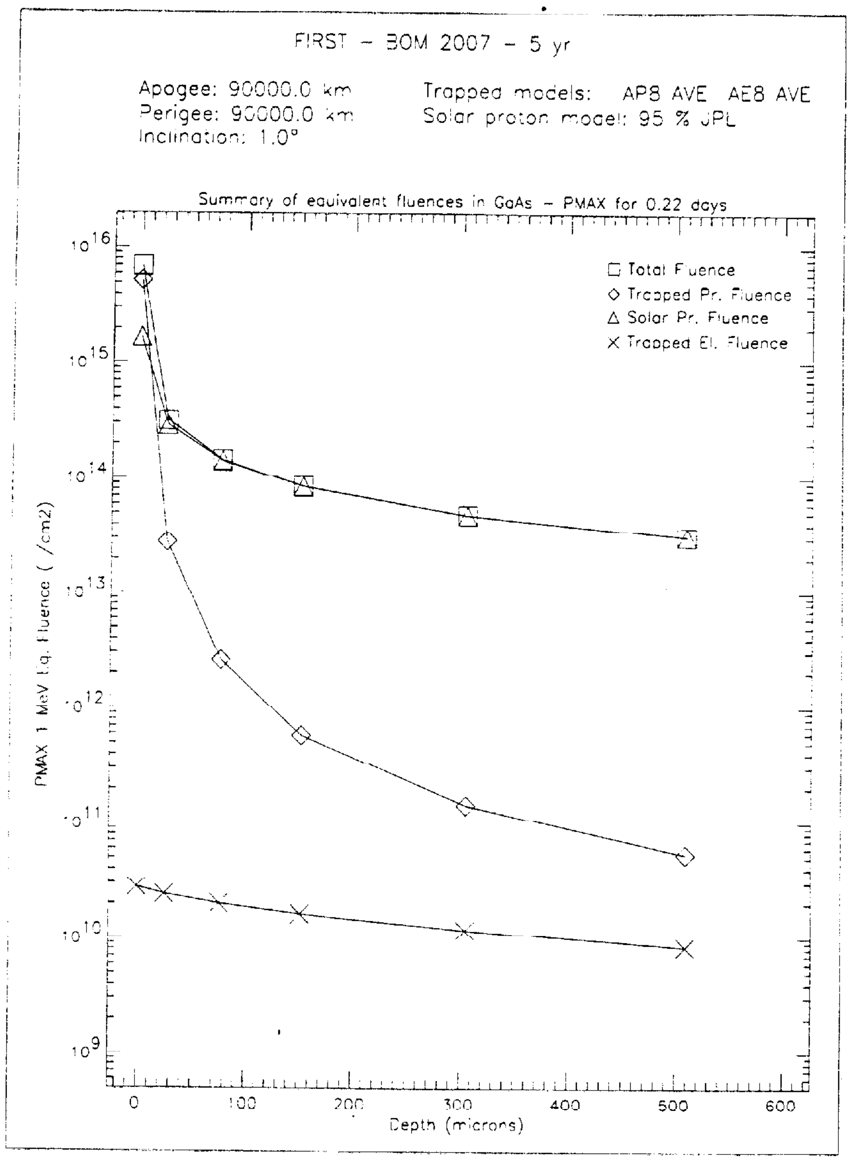


Figure 33. Equivalent Gallium Arsenide 1 MeV P_{MAX} electron fluence for the five year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.

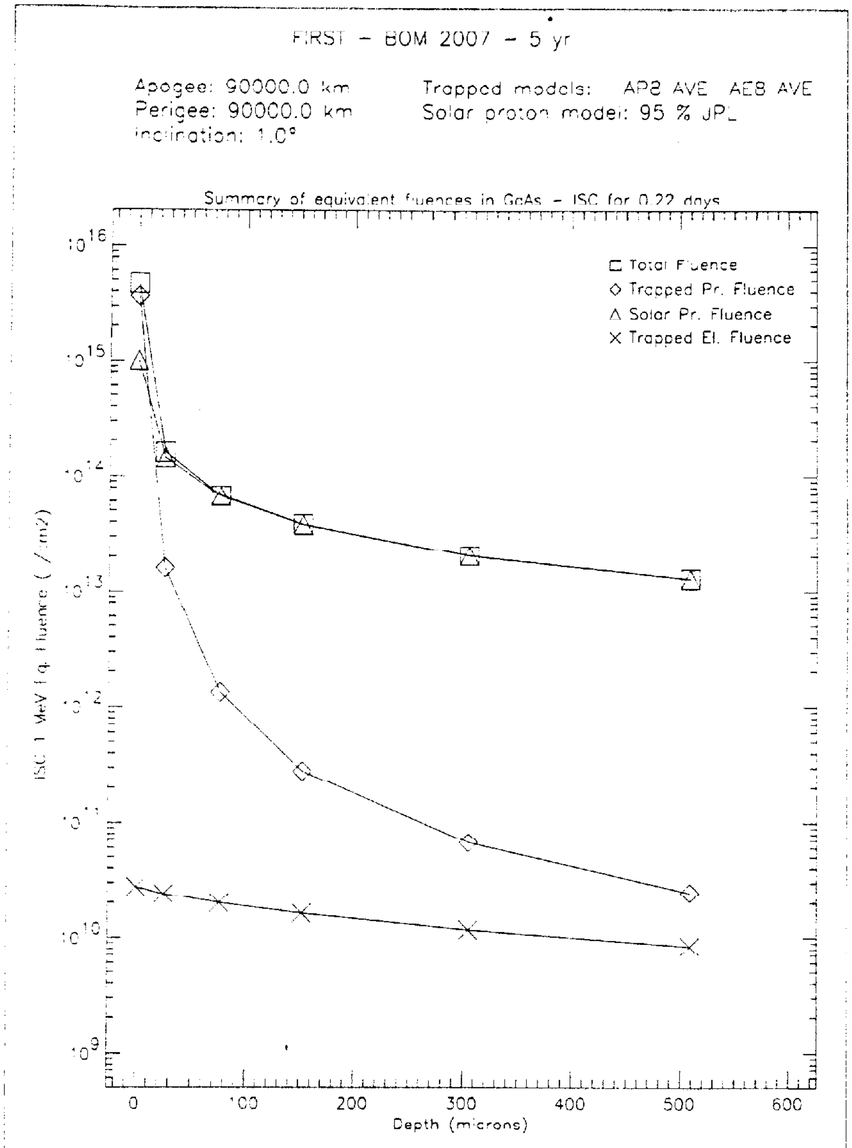


Figure 34. Equivalent Gallium Arsenide 1 MeV I_{SC} electron fluence for the five year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.

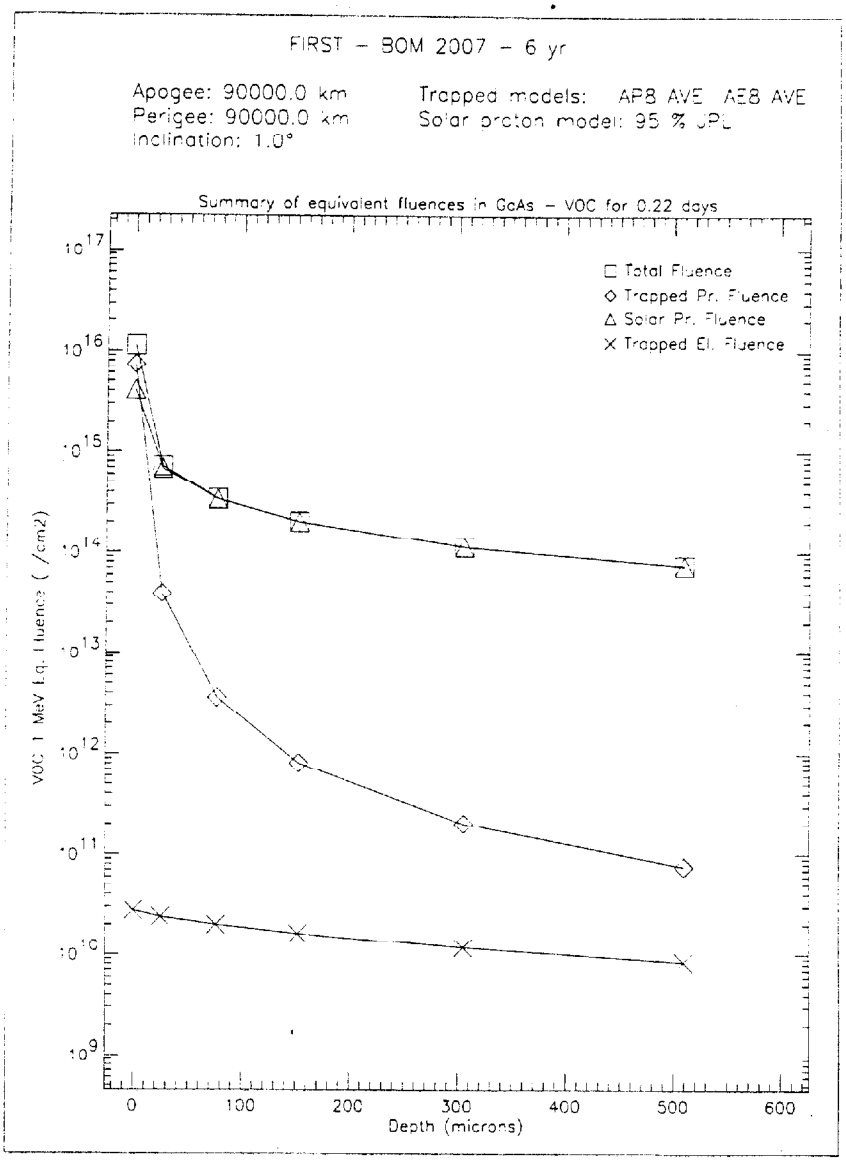


Figure 35. Equivalent Gallium Arsenide 1 MeV V_{OC} electron fluence for the six year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.

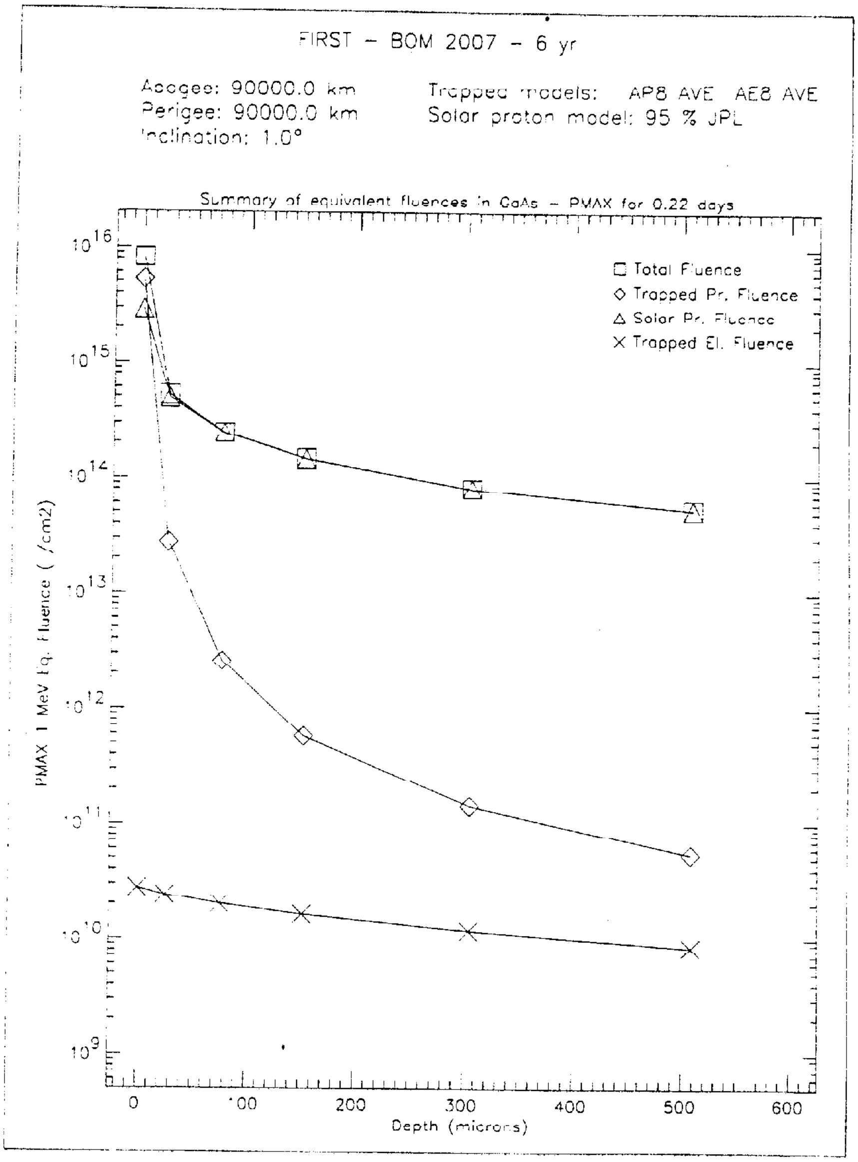


Figure 36. Equivalent Gallium Arsenide 1 MeV P_{MAX} electron fluence for the six year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.

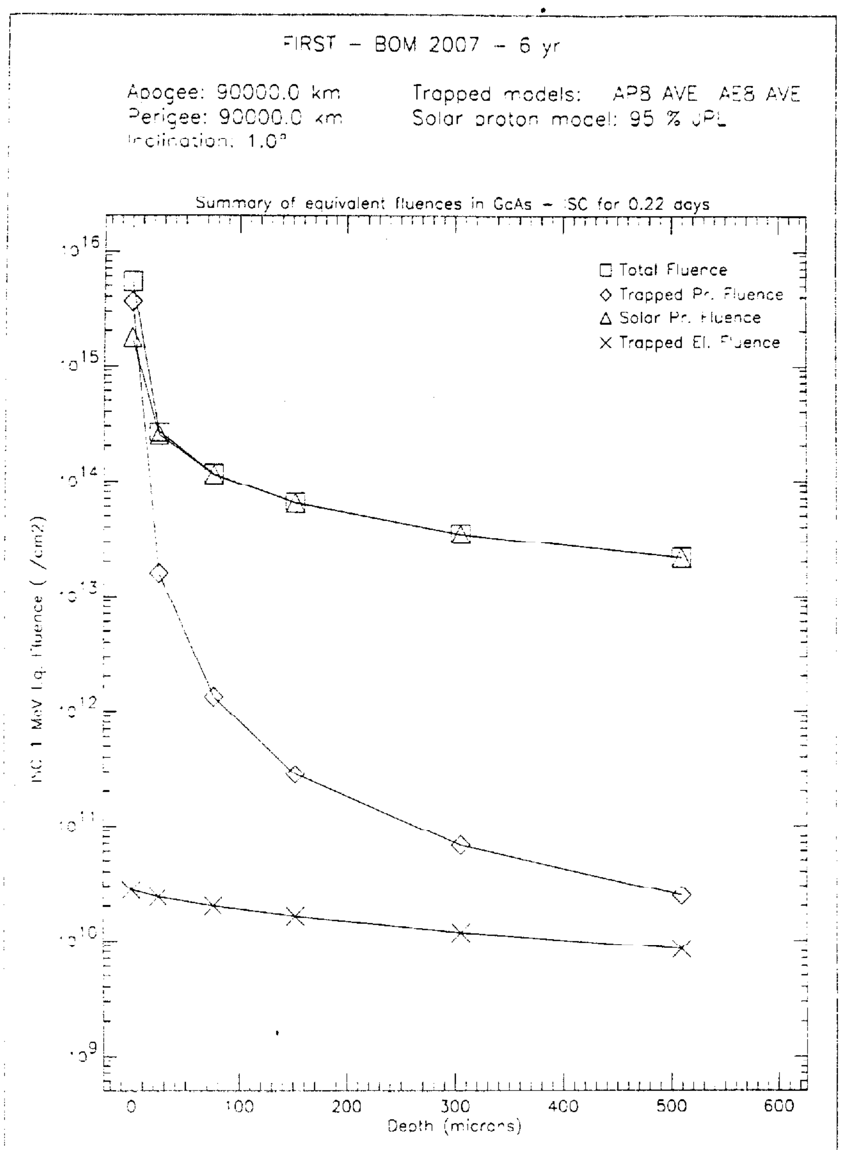


Figure 37. Equivalent Gallium Arsenide 1 MeV I_{SC} electron fluence for the six year mission commencing in 2007. This includes the trapped particle contribution from the Ariane V injection trajectory.