FOR

~~LSS~~ CMB

final briefing — phase 2

EXTRACTS FROM

SOLAR POWER SATELLITE SYSTEM DEFINITION STUDY

GRUMMAN AEROSPACE CORPORATION

NUMBER OF BASE PERSONNEL

Personnel requirements established by Boeing for operational SPS maintenance and flight transportation vehicles maintenance are added to the GEO Base construction crew. When 20 to 60 satellites are being maintained the total personnel complement varies from 827 to 1593 people. The maximum number of personnel on one shift has been totaled at 648. There are times when the personnel on duty could be considerably less, i.e., during the construction crew's time off.

NUMBER OF BASE PERSONNEL

DISCIPLINE	TOTAL CREW	ONE SHIFT CREW
SPS CONSTRUCTION	(417)	(199)
BASE MANAGEMENT	17	17
CONSTRUCTION	262	131
BASE SUPPORT & OPERATIONS	120	45
OPERATIONS SAFETY	18	6
FLIGHT TRANSPORTATION MAINT	(27)	(14)
EOTV SUPPORT	8	4
OTV SERVICING	19	10
SUBTOTAL	444	213
SPS MAINTENANCE (20 TO 60 SATELLITES)	(383 TO 1149)	(145 TO 435)
REPAIR EQUIPMENT	260 TO 780	130 TO 390
MOBILE MAINTENANCE	83 TO 249	NA
CREW SUPPORT	40 TO 120	15 TO 45
TOTALS	827 TO 1593	358 TO 648

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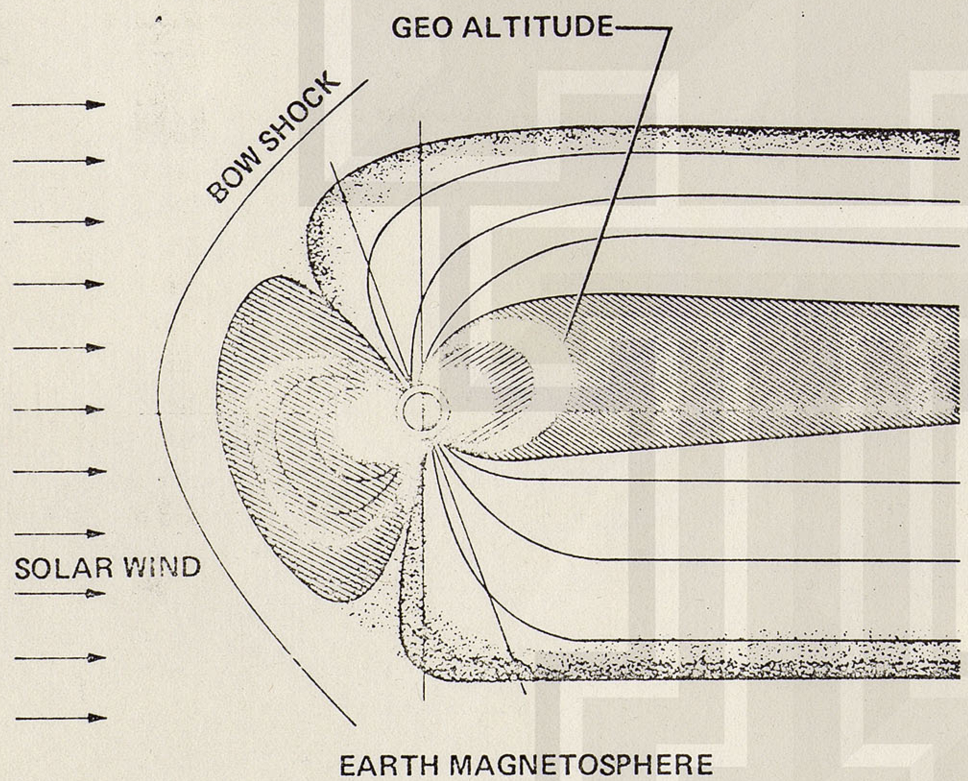
1622-012W

SPS GEO RADIATION SOURCES

This illustration shows the magnetosphere and the radiation sources to which SPS systems and the assembly and maintenance crew will be subjected.

- The major sources of radiation at GEO orbit are the geomagnetically trapped electrons and protons, galactic cosmic rays and solar flare event particles.
- The trapped radiation particles undergo large temporal fluctuations (diurnal and during magnetic storm activity).
- Types of ionizing radiation important to SPS operations:
  - Electrons and secondary radiation: bremsstrahlung (with variation of factor of two due to parking longitude location)
  - Protons (flux from solar flare protons dominates) and secondary radiation protons, neutrons
  - Heavy ions (HZE), secondary radiation: protons, neutrons and lighter nuclei.
- Other sources
  - Onboard nuclear powered payloads and equipment
  - X-Ray equipment
  - Possible nuclear weapon detonations.

SPS GEO RADIATION SOURCES



- TRAPPED ELECTRONS & PROTONS
- GALACTIC COSMIC PARTICLES
- SOLAR FLARES
- OTHER SOURCES

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RADIATION EXPOSURE LIMITS & CONSTRAINTS (REMS)

This chart lists the current astronaut radiation exposure limits as defined by the National Academy of Science/Radiobiological Advisory Panel/Committee on Space Medicine in 1970. These astronaut radiation exposure limits are based upon a 5-year career and are presently included in the STS Payload Safety Guidelines Handbook. These limits are, of course, intended to cover all forms of ionizing radiation (natural and induced). Comparable radiation exposure limits are also shown for industrial workers, as defined by the Department of Labor OSHA regulations. The low OSHA limits are also contrasted with the maximum radiation limit allowed for each Apollo mission.

It is interesting to note that the average skin dose experienced by the Apollo astronauts was very low (about 1 rem), since no solar event occurred. Nevertheless the maximum limit for Apollo was established for a program of national importance that included less than one hundred volunteer astronauts. The OSHA standards, of course, apply to millions of industrial workers. The SPS construction base is presently estimated to have approximately 800 workers on board, which equates to a 10,000 man work force over a 30-year period. Hence, allowable SPS radiation limits may have to be established with respect to societal considerations.

RADIATION EXPOSURE LIMITS & CONSTRAINTS (REMS)

SHOULD INDUSTRIAL LIMITS APPLY TO SPS GEO SPACE WORK FORCE?

	ASTRONAUT*			INDUSTRIAL WORKER**	APOLLO MAX LIMIT
	SKIN (0.1mm)	EYES (3mm)	BONE MARROW (5cm)	BFO & EYES	BFO & SKIN
1 YR AVG DAILY RATE	.6	.3	.2		65 & 520*** PER MISSION
30-DAY MAXIMUM	75	37	25		
QUARTERLY MAXIMUM	105	52	35	3	
YEARLY MAXIMUM	225	112	75	5	
CAREER	1200 (5 yr)	600	400	235 (@ 65)	

* SPACE TRANSPORTATION SYSTEM PAYLOAD SAFETY GUIDELINES HDBK NASA/JSC - JSC 11123, JULY 1976

** FEDERAL REGULATIONS - LABOR PART 1910 OSHA - 1 JULY 1978

*** APOLLO MISSIONS 7 TO 17 ONLY HAD ~ 1 REM AVG SKIN CREW DOSE-SINCE NO MAJOR SOLAR PARTICLE EVENTS OCCURRED

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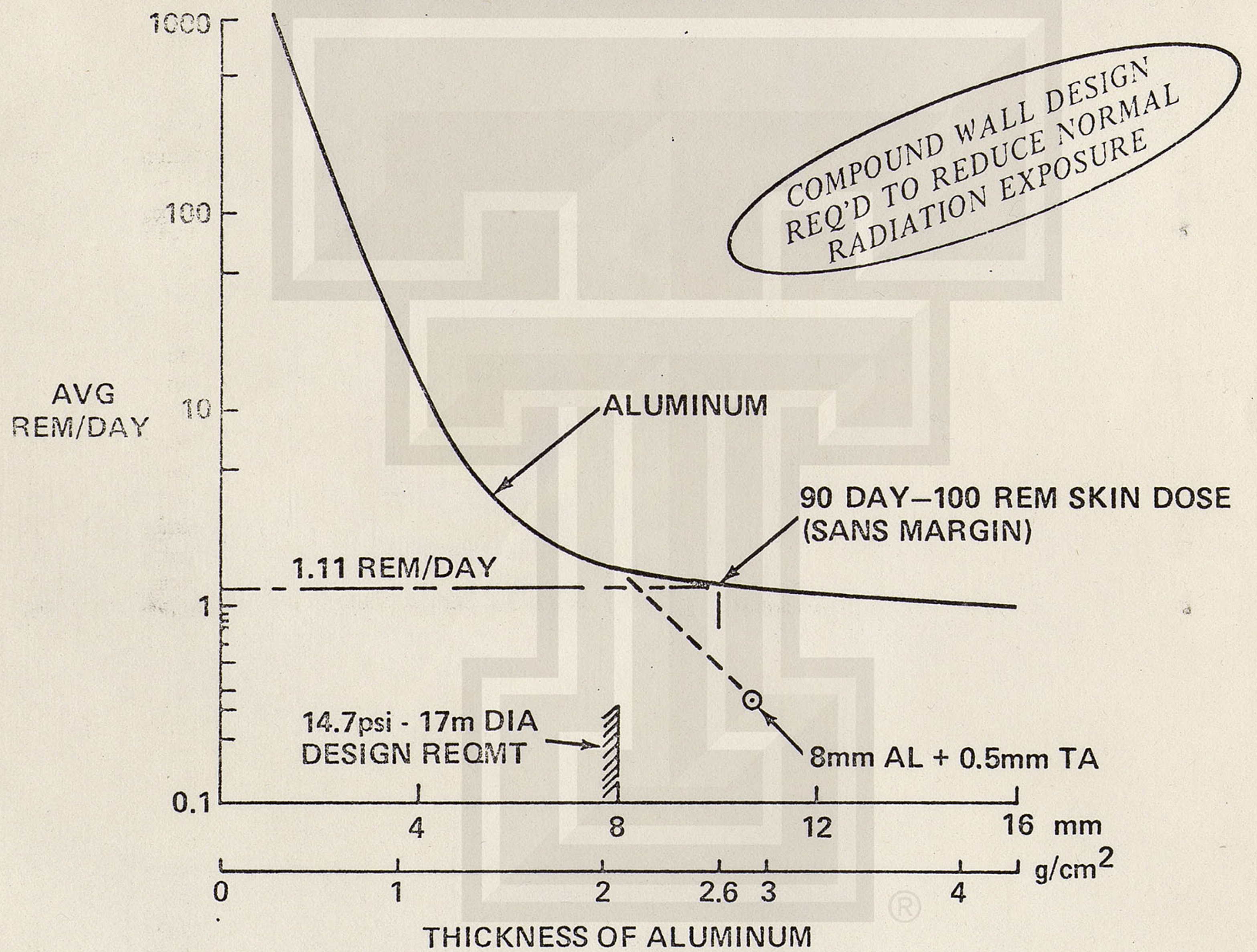
SHIELDING THICKNESS FOR GEO TRAPPED ELECTRONS PLUS BREMSSTRAHLUNG

The average REMs that a crew member will experience each day in geosynchronous orbit is plotted as a function of equivalent aluminum cabin wall thickness, as shown on the facing page. In order to reduce the skin dose to 1.11 REMs per day for the maximum quarterly exposure limit (i.e., 105 REMs less 5 REMs for OTV LEO/GEO transit) at least 10 mm of aluminum should be provided. Aluminum is not a very effective shield for this level of radiation due to Bremsstrahlung (secondary radiation) effects. However, by adding a thin inner layer of tantalum, the cabin radiation level can be lowered to provide a margin for other unscheduled radiation conditions (e.g., x-ray inspection, etc.). The use of compound wall design techniques is an effective way of coping with Bremsstrahlung which provides increased radiation protection for minimum shield thickness and weight. Practical shielding designs that can reduce the daily dose rate to OSHA levels require further study and remain as a technology issue.

SHIELDING THICKNESS FOR GEO TRAPPED ELECTRONS PLUS BREMSSTRAHLUNG (270° EAST LONGITUDE)



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SOLAR FLARE RADIATION PROTECTION REQUIREMENTS

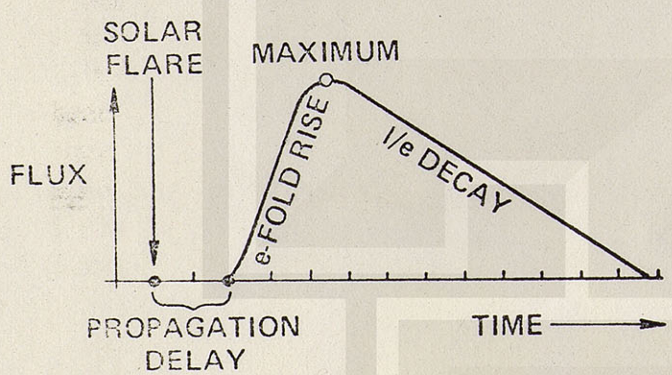
The GEO base solar flare radiation protection system must be able to provide timely warning of a high energy solar event, so that the crew can safely reach a radiation shelter to ride out the storm. The characteristics of a typical solar event are shown on the facing page, together with related data on the severity and duration of prior solar events. Minimum aluminum shielding thickness requirements are provided.

Once a solar flare is observed, a 20 to 30 minute delay occurs in particle propagation before an increase in the background energy level is detected. From the onset of increased radiation, the maximum flux level may be attained within 15 minutes to a few hours according to T. Wilson et al (NASA TND 8290, 1976). However, recent communication with G. Heckman at the Boulder NOAA, Space Environment Laboratory indicates that maximum flux rise time occurs less rapidly, from 2 to 100 hours. The corresponding time delay for the first particle to arrive is about 1/3 to 1/2 of the time to reach peak intensity. The peak intensity, in turn, may last only intermittently or for a few hours and the subsequent decay period may be over in a matter of hours or days. Data from the 20th solar cycle shows that the highest energy event recorded lasted for five days and that a few lower energy events lasted 10 days. Hence, the radiation storm shelter must be able to support the crew life support functions for several days.

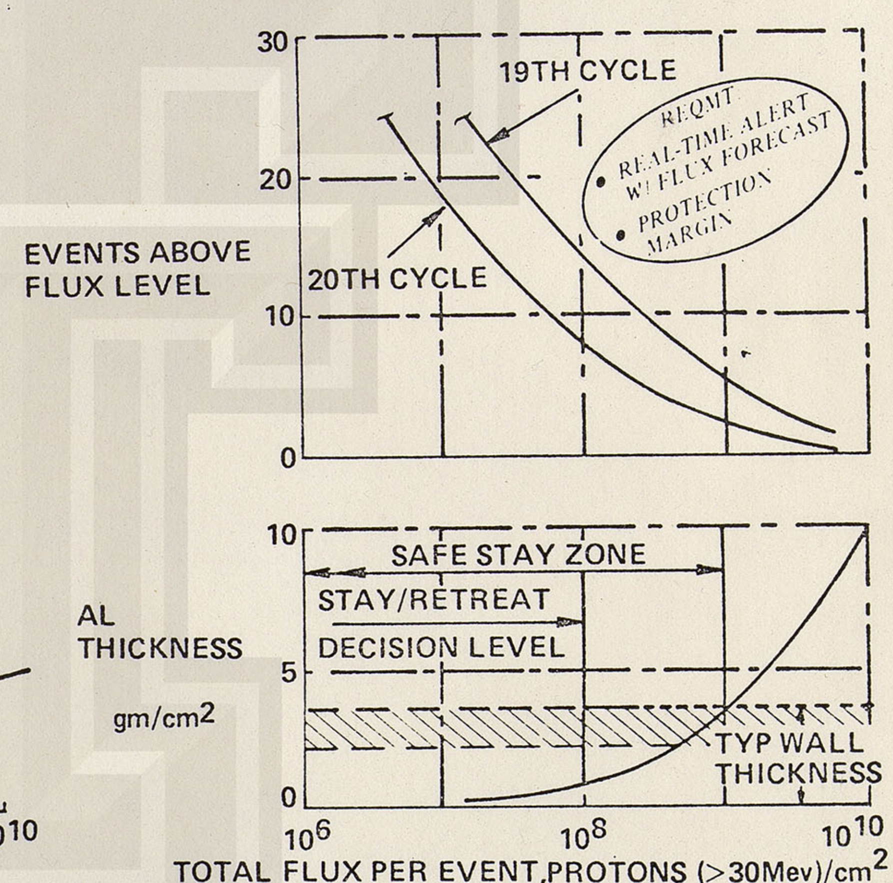
In the upper right part of the chart, the frequency of solar events is plotted as a function of the severity of the event (protons/cm^2). Smoothed historical data are shown for the two most recent solar cycles. Cycle 21 is now underway and resembles cycle 19 rather than cycle 20. The lower righthand part of the figure shows the cabin wall thickness necessary to protect against this range of event sizes. A typical cabin wall thickness needed for shielding trapped electrons in GEO is also shown at 2.6 to 4 gm/cm^2 (i.e. 1.0 to 1.5 cm of aluminum). A 4 gm/cm^2 shield gives protection for any event up to 1×10^9 p/cm^2 flux, however, a minimum thickness of 10 gm/cm^2 is needed for a major solar event (Aug 1972) provided the crew is also equipped with personal shielding for the eyes and testes during peak exposure. Development of a real time solar flare alert system with flux forecast is needed. If the alert system can be triggered at predetermined energy levels below the nominal wall radiation protection level, then a built-in margin for error in forecasting accuracy could be achieved.

SOLAR FLARE RADIATION PROTECTION REQUIREMENTS

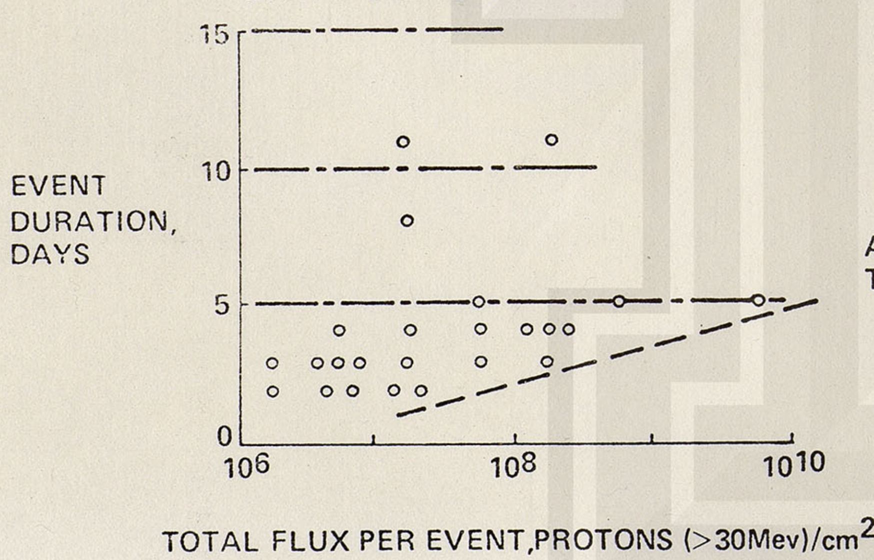
SOLAR EVENT CHARACTERISTICS



SOLAR EVENT FREQUENCY &
MIN SHIELDING THICKNESS



20TH CYCLE SOLAR EVENT DATA



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1622-007W

SPS GEO BASE RADIATION DESIGN CONSIDERATIONS

The allowable crew dose for the SPS GEO construction base remains to be established. Total accumulated dose limits are required for the entire mission profile, that is, time in LEO, LEO/GEO transit and the GEO base. How much margin should be provided for unscheduled exposure and whether the astronaut allowed radiation levels are applicable to SPS are areas for further study.

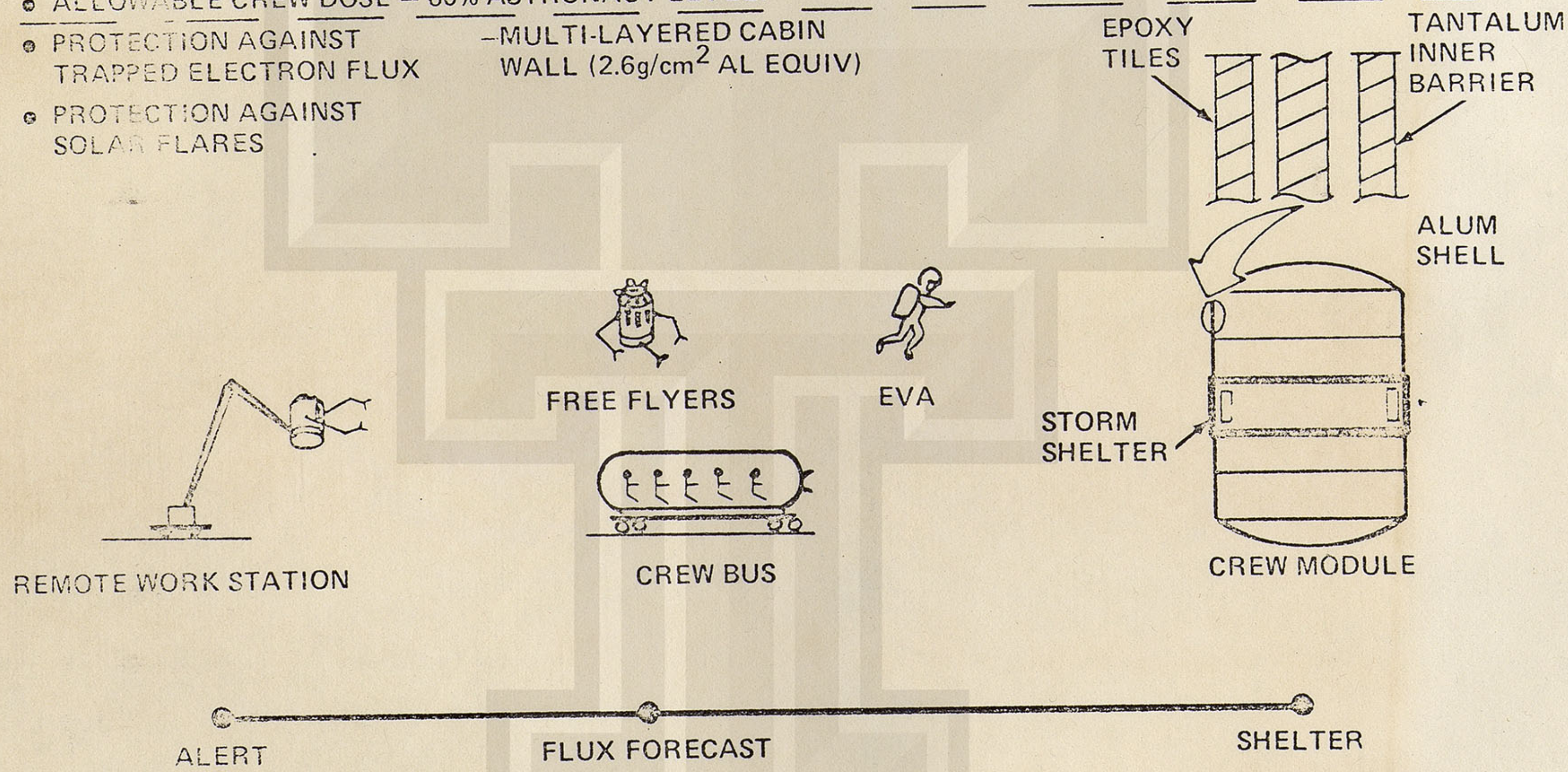
Protection against trapped electron flux in geosynchronous orbit must be factored in all aspects of GEO base operations and design, which include IVA assignments in remote work stations, free fliers, crew bases and crew habitation modules. We propose a multilayered cabin wall of 2.6 gm/cm^2 aluminim equivalent for the crew module as shown in the figure. The other IVA crew stations could be designed with lighter shielding provided that the total allowable dose is not exceeded. In addition, if EVA operations are needed they should be conducted near local midnight to minimize normal belt radiation exposure. However, EVA should be avoided during large scale fluctuations due to geomagnetic disturbances. The present SPS suit must be upgraded to provide added protection for GEO EVA (i.e., between 1.5 and 4 mm equivalent aluminum.)

Protection against solar flares requires an adequate flare alert warning system that will allow all GEO base workers on remote IVA or EVA assignments to retreat to the nearest storm shelter. Means for protecting stranded workers at these remote locations need to be considered together with the systems required to implement their rescue. The storm shelter is provided with 20 gm/cm^2 of multilayered aluminum equivalent thickness. Additional shielding benefits can be attained by placing internal equipment arrangements against the outer wall.

Protection against high energy heavy ions (HZE) requires further study. Although the dose from these HZE particles is small it is important because of possible biological effects.

SPS GEO BASE RADIATION DESIGN CONSIDERATIONS

- ALLOWABLE CREW DOSE – 60% ASTRONAUT LEVEL?
- PROTECTION AGAINST TRAPPED ELECTRON FLUX – MULTI-LAYERED CABIN WALL ($2.6 g/cm^2$ AL EQUIV)
- PROTECTION AGAINST SOLAR FLARES



- HZE BIOLOGICAL EFFECTS/PROTECTION?

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