International Conference
MOON BASE
a Challenge for Humanity

RADIATION SAFETY SUPPORT of INTERMEDIATED SPACE STATION CREWS, in L1 and L2, and on the MOON

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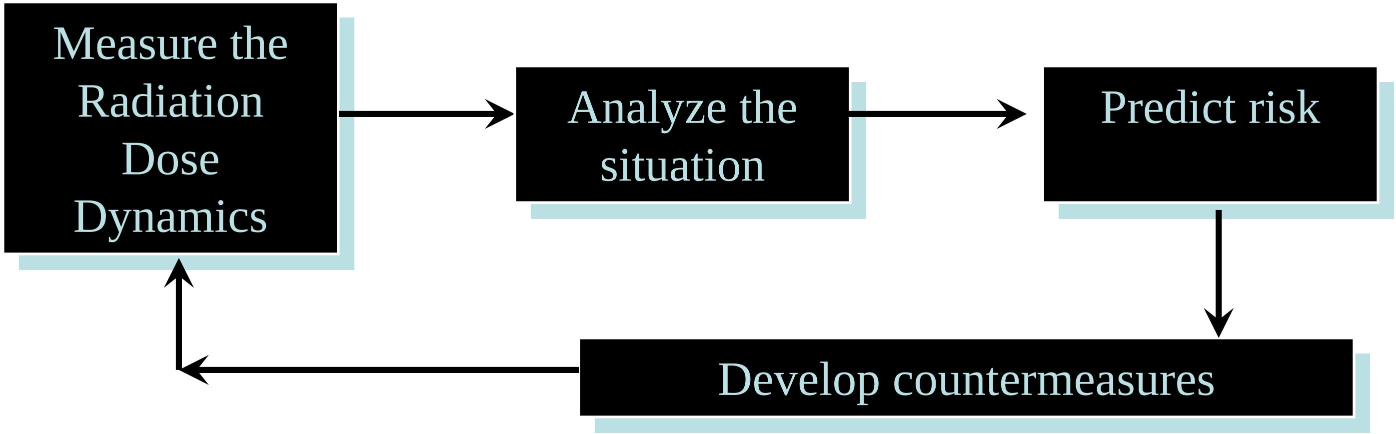
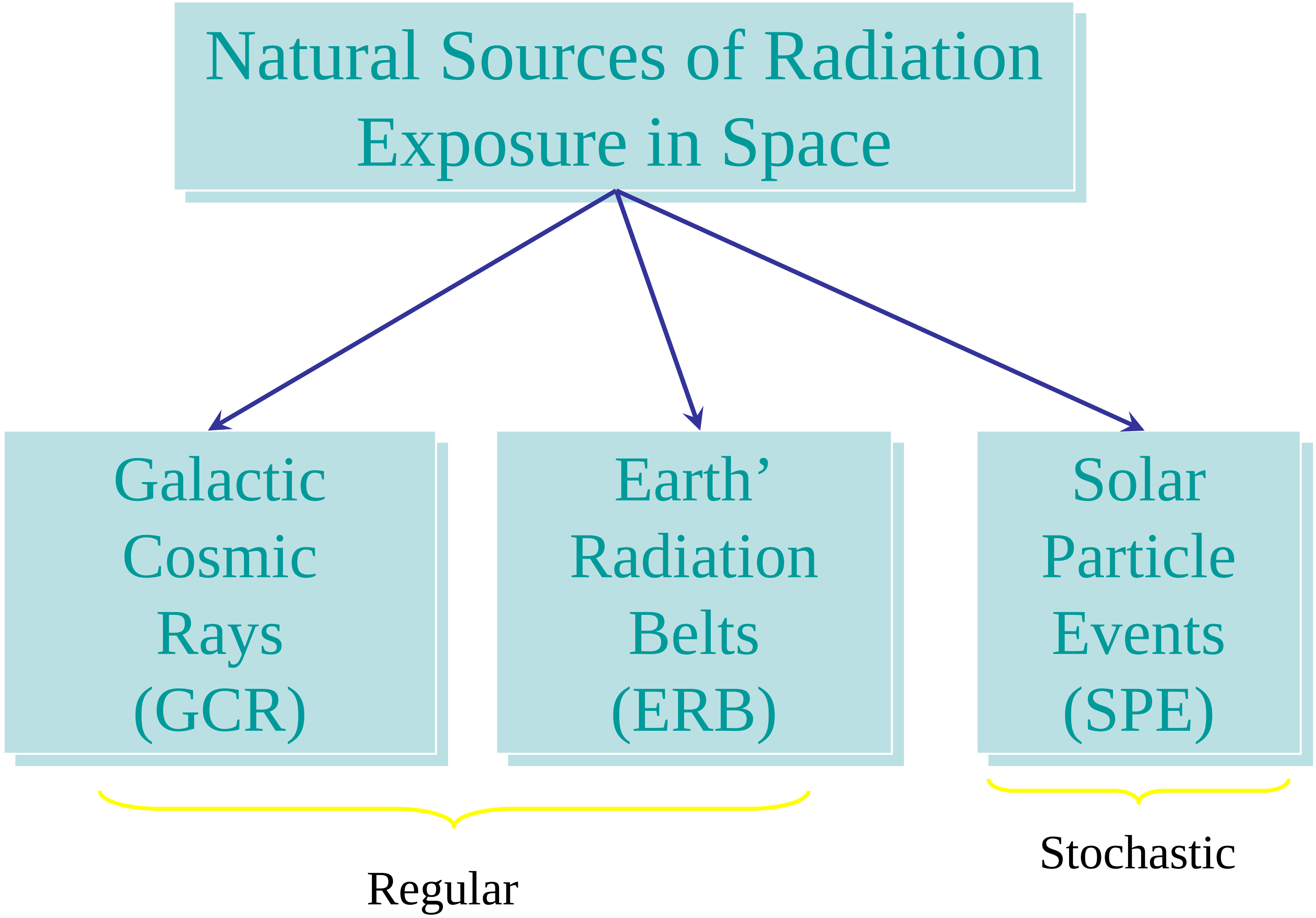
Radiation Protection of the Manned Mission

<u>GOAL</u>: enable safe manned mission and returning to the *Earth* by ensuring that the risk from exposure to space radiation is at all times below acceptable risk levels.




Natural Sources of Radiation Exposure in Space
Galactic Cosmic Rays (GCR)
Earth' Radiation Belts (ERB)
Solar Particle Events (SPE)
Regular
Stochastic

MIR or ISS orbit

- D(Space Flight) = D(ERB) + D(GCR) + D(SPE)
- In normal conditions (no SPE):
- D(Space Flight) = D(ERB)+D(GCR) = from 0.3 to 0.8 mSv/day

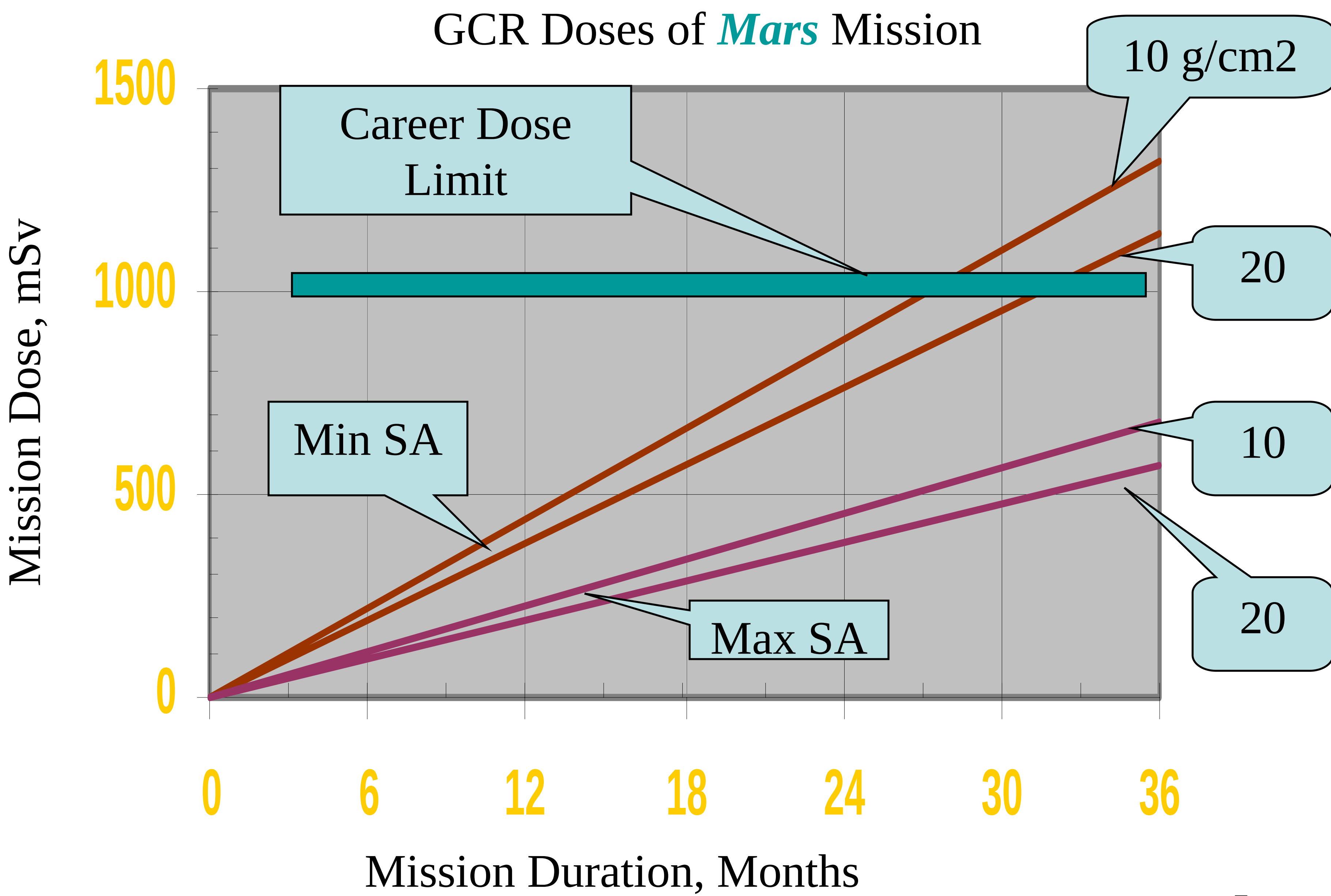
INTERPLANETARY MISSION

- D(Space Flight) = 2*D(GCR) + 300*D(SPE)
- In normal conditions (no SPE):
- D(Space Flight) = 2*D(GCR) = from 0.3 to 0.8 mSv/day

Exposure Period	Dose, mSv
One day on the Earth	**0.0025**
Typical non-disturbed day in Space (MIR or ISS)	**0.5**
One year in Space = 0.5 x 365	**180**
Annual Dose Limit for Space Missions	**500**
Annual Dose Limit for Radiation Personnel on the Earth	**20**
Exposure from a typical chest X-ray	**0.1**
Career Dose Limit on the Earth = Career Dose Limit in Space	**1000**

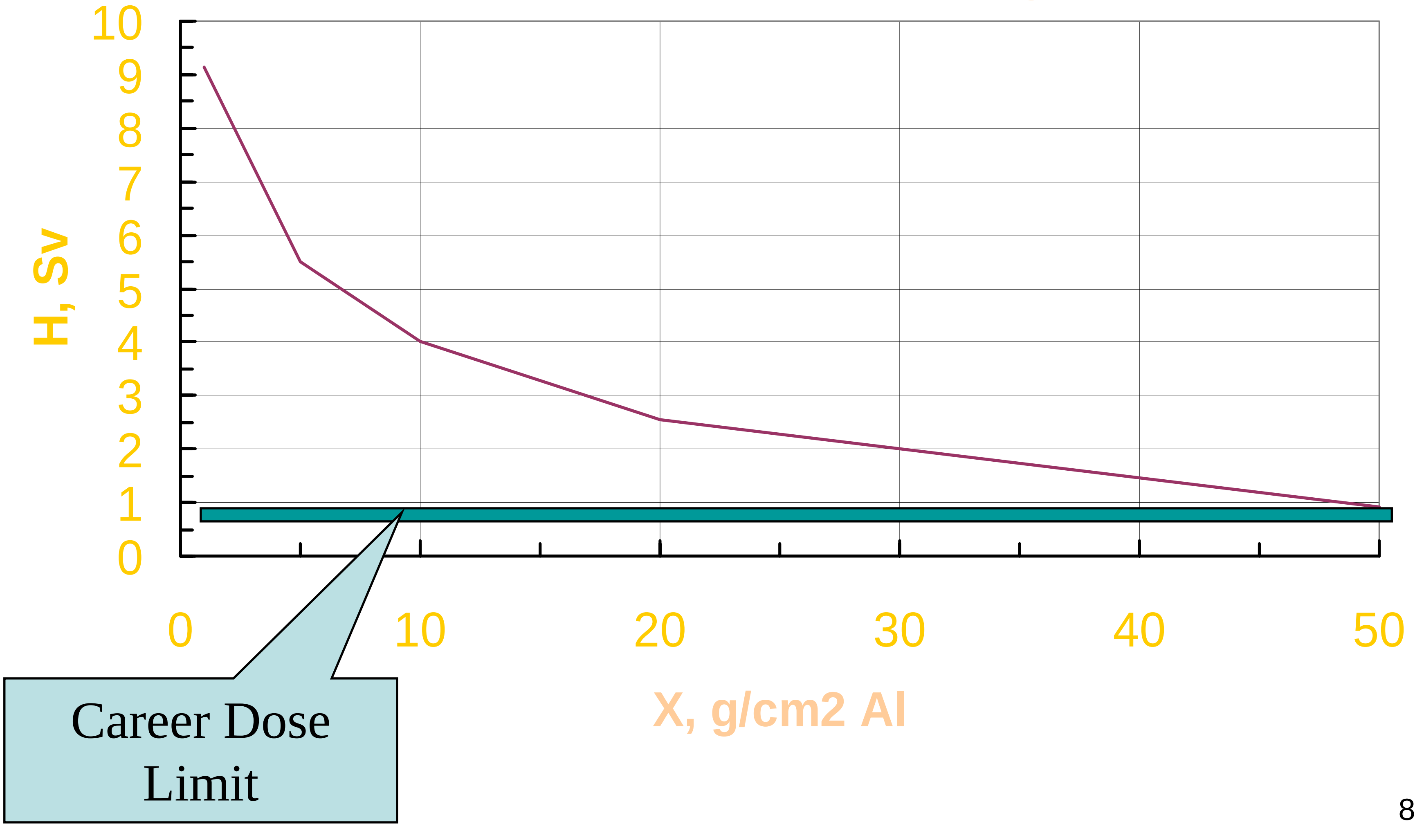
Practical Measures for Radiation Risk Mitigation

- Choice of proper flight period and trajectory
- Spacecraft shielding optimization
- In-flight radiation monitoring and risk forecasting
- EVA planning
- Crew selection based on individual radiation sensitivity


GCR Doses of Mars Mission
10 g/cm2
20
10
20
Career Dose Limit
Min SA
Max SA
1500
1000
500
0
Mission Dose, mSv
0
6
12
18
24
30
36
Mission Duration, Months

Once per $7 \cdot 10^3$ years

The Worst Case SCR BFO Dose Versus Shielding



Radiation Dose on the ***Moon*** Surface

GCR Dose =

= from 80 to 150
mSv/year

Radiation shelter from SPE on the *Moon* surface is necessary

P.Saganty et.al., 2002, JSC NASA

http://ails.arc.nasa.gov/Images/Space/jpegs/

Spacecraft Shielding Optimization

- Choice of proper materials for particle deceleration and stopping (passive shielding)
- Particle trajectory changing by an artificial magnetic fields around the spacecraft (active shielding)

Usage of the most protected compartment as ***a radiation shelter***

- *P.Spillantini et al.* **Shielding from cosmic radiation for interplanetary missions: active and passive methods**[a]

In-flight Radiation Monitoring and Risk Forecasting

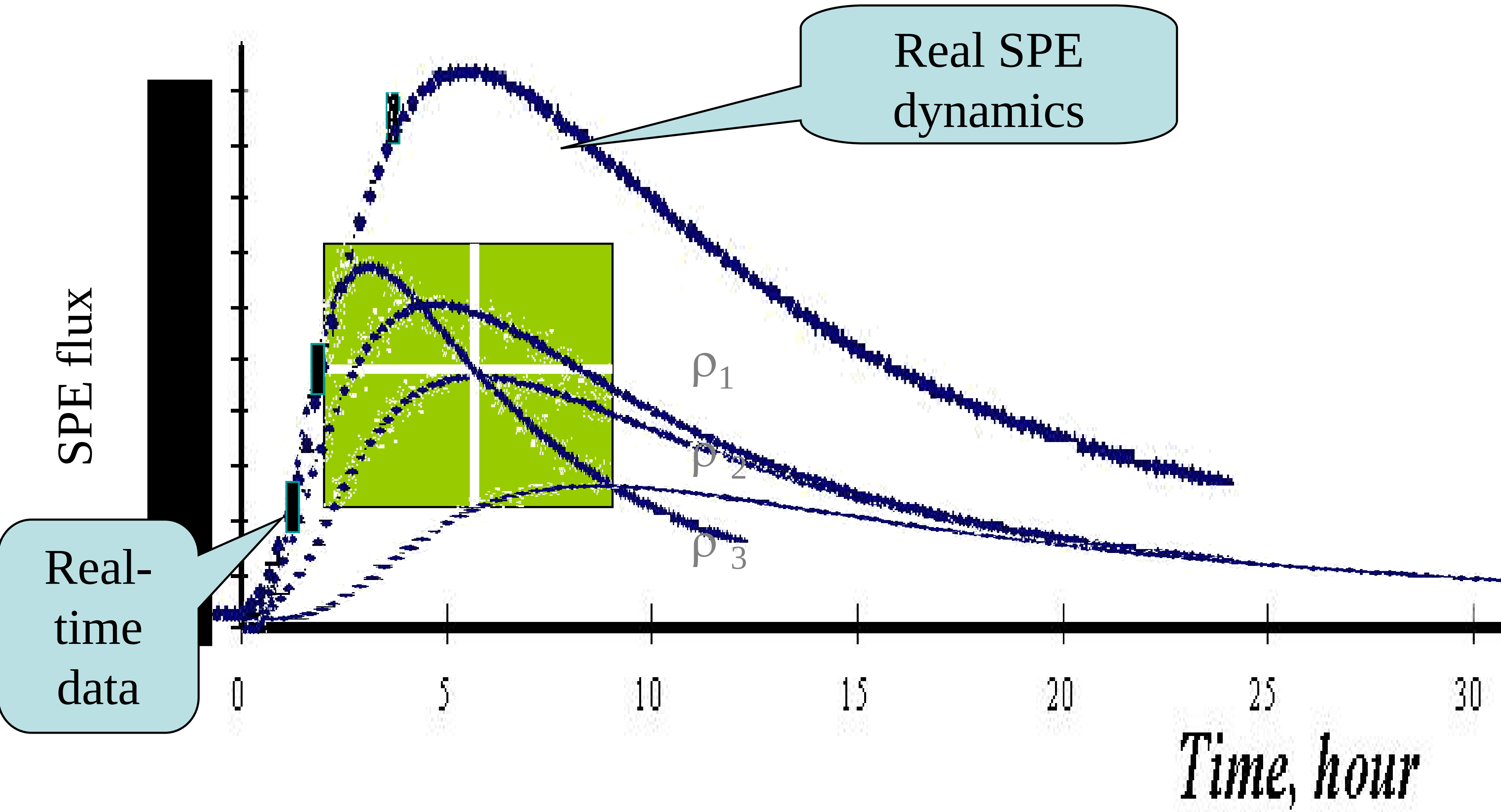
Radiation Monitoring System (RMS) = radiation detectors

+ real-time data analysis by on board computer
+ issuing of recommendations to the crew members

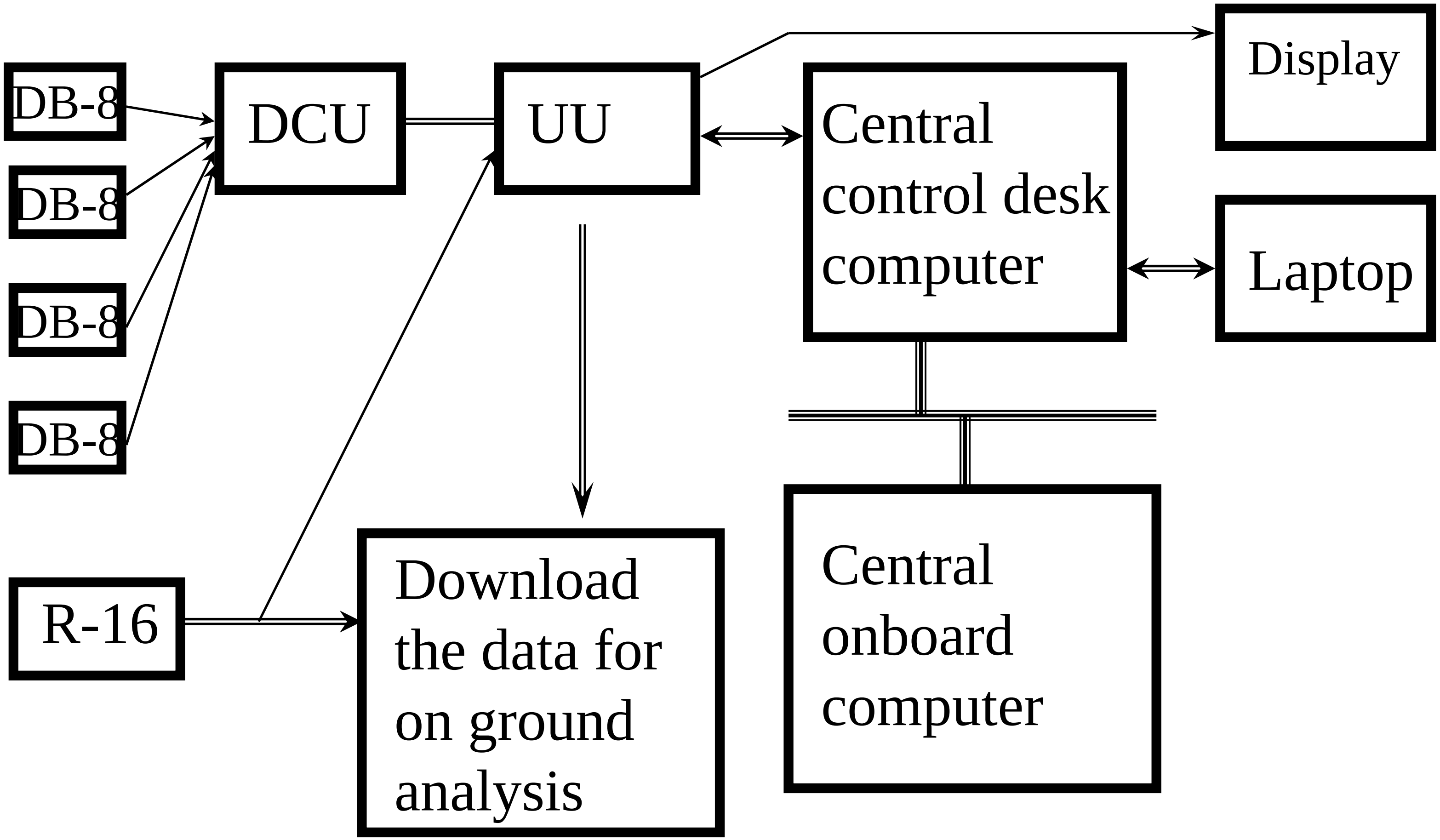
Forecasting Method of the SPE Radiation Exposure Levels

- Forecast the dynamics of the proton spectrum that comes to the spacecraft;
- Calculate radiation exposure levels in the station compartments based on the expected proton spectrum and spacecraft shielding.

Forecasting of the SPE flux dynamics

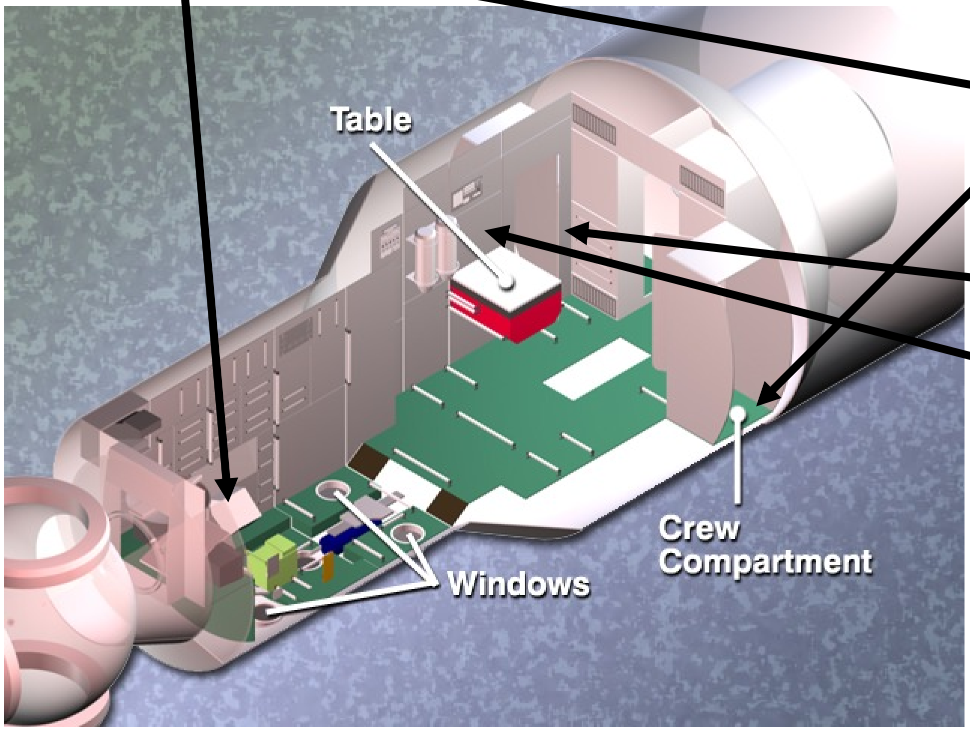


The ISS Radiation Monitoring System



The RMS has been operating since August 1, 2001 12:42 UT.

Locations of the RMS Detectors

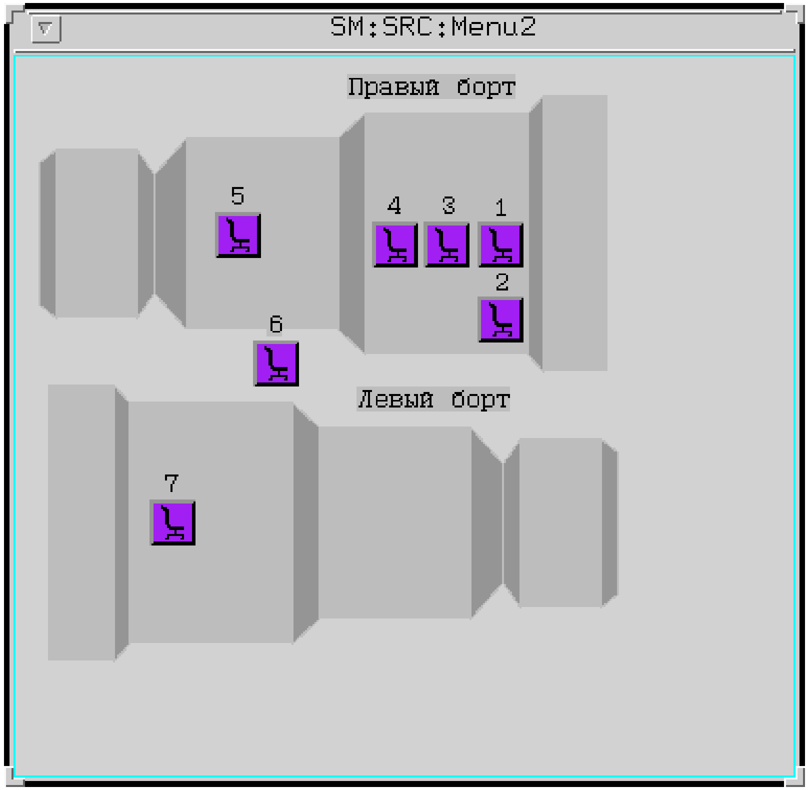


http://spaceflight.nasa.gov/gallery/images/station

/servicemodule/html/jsc2000e26922.html

Block	Placement
DB-8 №1	Starboard side, behind board № 410
DB-8 №2	Port side, behind board № 244 (cabin)
DB-8 №3	Starboard side, behind board № 447 (cabin)
DB-8 №4	Starboard side, behind board № 435
R-16	Ceiling of Big diameter bay, behind board № 327
UU	Starboard side, behind board № 447 (cabin)
DCU	starboard side, behind board № 447 (cabin)

An Example the RMS Information at the Onboard Display



Crew Selection Based on Individual Radiation Sensitivity

- Test of the preflight level of chromosome aberrations in lymphocytes
- Blood sample analysis after radiation exposure (*in vitro*)
- Search for additional indications of high radiation sensitivity

CONCLUDING REMARKS

- Exposure to radiation during space flight is unavoidable
- For the outside Earth' magnetosphere missions, the space radiation dose can be hazardous for cosmonauts' life
- For in-time measures against the additional radiation exposure of the crewmembers, forecasting of radiation environment onboard the spacecraft is extremely important

CONCLUDING REMARKS

- An international collaboration of world space agencies is necessary to improve the reliability of our knowledge on radiation safety of the ***Exploratory*** missions and reduce risk uncertainties for the space travelers

The END