ADVANCED MULTIFUNCTIONAL MMOD SHIELD: RADIATION SHIELDING ASSESSMENT

Kristina Rojdev, Ph.D.

Eric Christiansen

OUTLINE

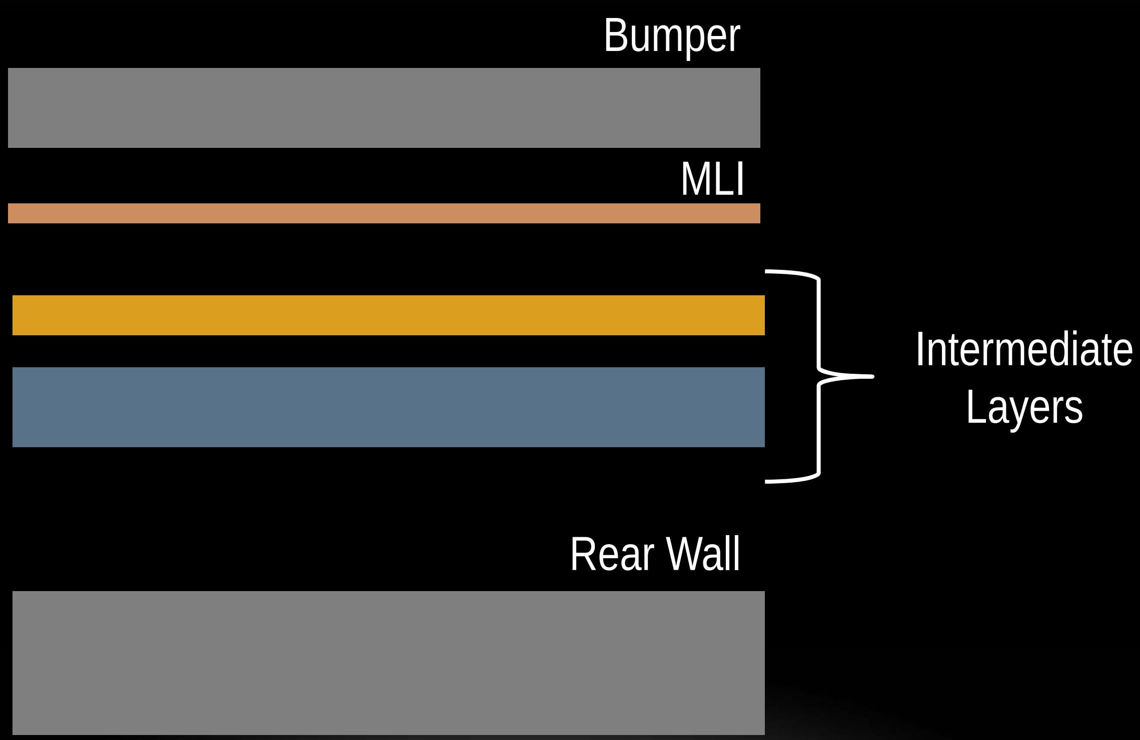
- Introduction
- Background
- MLI Assessment
- MMOD Shield Assessment
- Summary and Conclusions

INTRODUCTION

- Deep space missions must contend with a harsh radiation environment
  - Impacts to crew and electronics
- Need to invest in multifunctionality for spacecraft optimization
- MMOD shield
  - Goals:
    - Increase radiation mitigation potential
    - Retain overall MMOD shielding performance

BACKGROUND: MMOD SHIELD

- Baseline: stuffed whipple shield derived from ISS



BACKGROUND: RADIATION ENVIRONMENTS

- Low Earth Orbit, (LEO), Galactic Cosmic Rays (GCR), Solar Particle Events (SPE)
- Four environments analyzed:
  - October 1989 SPE
  - 1982 GCR (during solar maximum)
  - 1987 GCR (during solar minimum)
  - LEO 1970 (altitude: 400 km, inclination: 51.6°)
- Analysis performed with HZETRN

MLI ASSESSMENT

- MLI baseline: ISS 40 layer configuration
- MLI concept: baseline MLI with additional layers

Type	10-1989 SPE	GCR 1982 (max)	GCR 1987 (min)	LEO
MLI Baseline	4.77E+04	8.41E-02	3.09E-01	2.08E-01
MLI Concept	1.66E+04	8.40E-02	3.07E-01	8.71E-02
% increase/ decrease	-65.14%	-0.13%	-0.55%	-58.19%
MMMOD Baseline	5.11E+02	8.31E-02	2.71E-01	3.22E-02
MMMOD Concept	4.87E+02	8.28E-02	2.69E-01	3.19E-02
% increase/ decrease	-4.63%	-0.40%	-0.60%	-1.07%

MMOD ASSESSMENT

- Material trades: bumper, intermediate layers, rear wall
  - MLI: ISS 40 layers
- 23 shield configurations

Shield #	Bumper	Intermediate Layers	Rear Wall	Total Thickness (g/cm^2)
1	Aluminum	ceramic/para-aramid	Aluminum	2.82
2	Aluminum	ceramic/polyethylene	Aluminum	2.81
3	Aluminum	Fiberglass/ polyethylene	Aluminum	2.82
4	Aluminum	Fiberglass/ polyethylene	Aluminum	2.77
5	Aluminum/ Fiberglass	Polyethylene	Aluminum	2.75

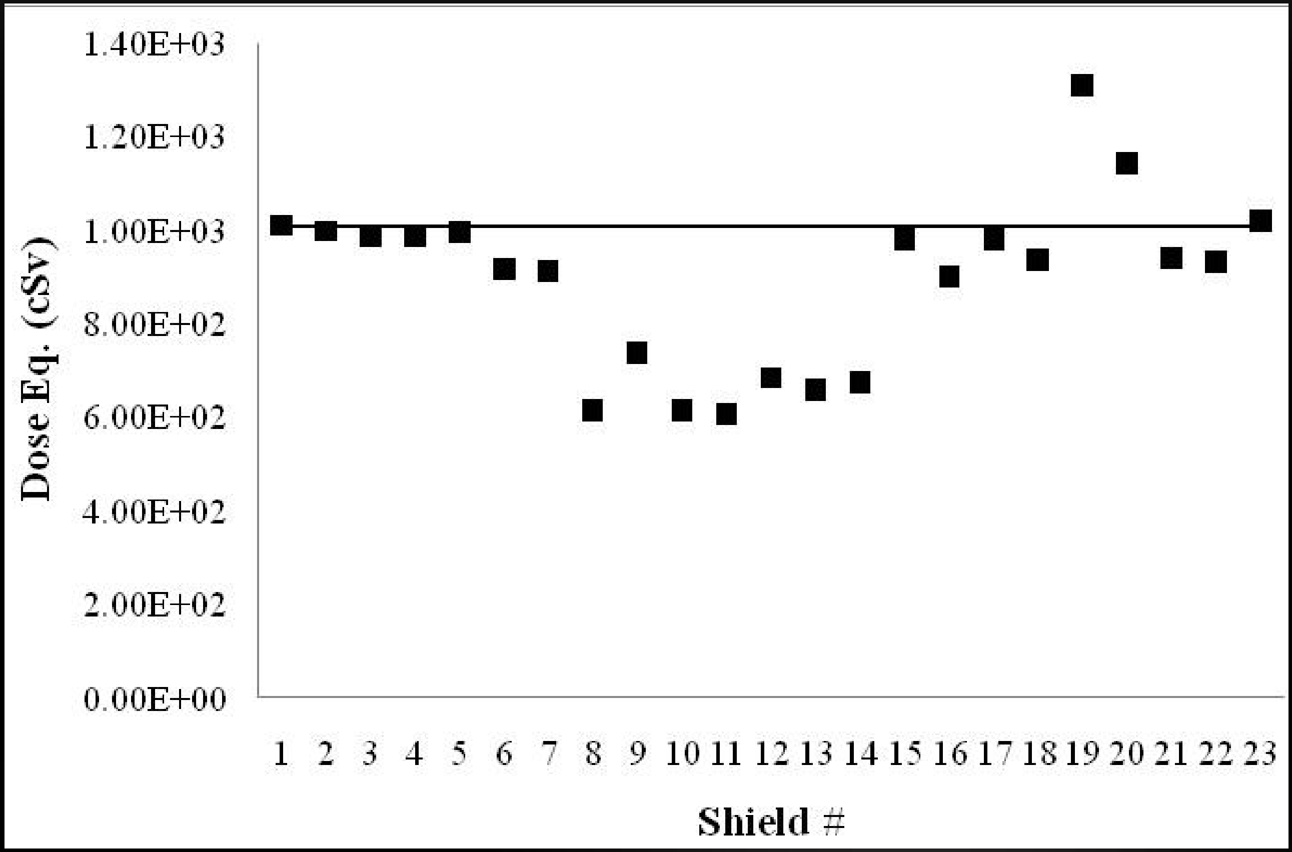
MMOD ASSESSMENT

Shield #	Bumper	Intermediate Layers	Rear Wall	Total Thickness (g/cm^2)
6	Aluminum	Fiberglass/ polyethylene	Aluminum	2.82
7	Aluminum	Polyethylene	Aluminum	2.80
8	Aluminum	Polyethylene	Polyethylene	2.80
9	Aluminum	Polyethylene	Polyethylene/ Aluminum	2.80
10	Aluminum	Fiberglass/ polyethylene	Polyethylene	2.83
11	Aluminum	Polyethylene	Polyethylene	2.83
12	Aluminum	Boron Carbide	Polyethylene	2.81
13	Aluminum/ Boron Carbide	Boron Carbide	Polyethylene	2.86
14	Aluminum	Polyethylene	Polyethylene	2.73

MMOD ASSESSMENT

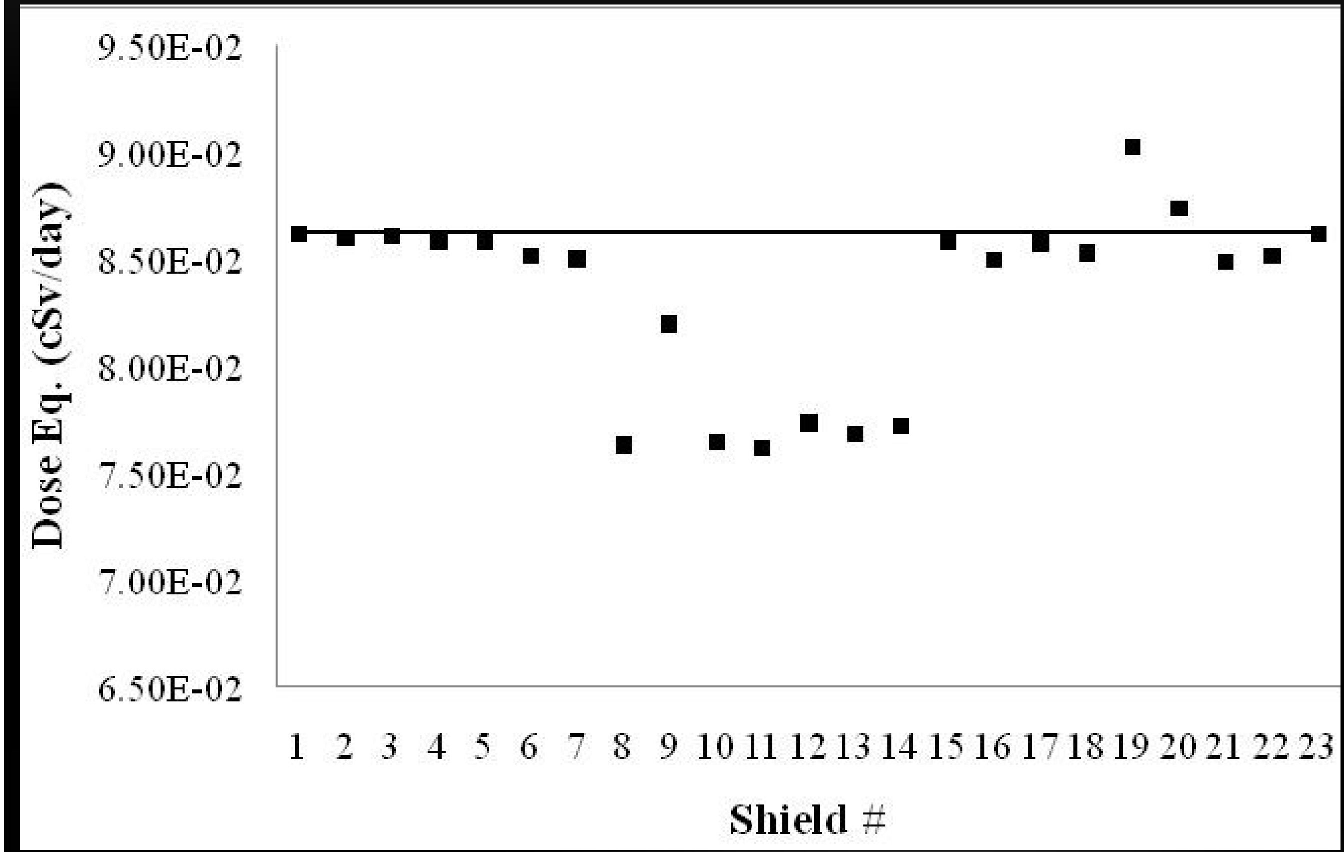
Shield #	Bumper	Intermediate Layers	Rear Wall	Total Thickness (g/cm^2)
15	Aluminum	Fiberglass/ polyethylene	Aluminum	2.78
16	Aluminum	Polyethylene	Aluminum	2.82
17	Aluminum	Silicon Carbide/ polyethylene	Aluminum	2.79
18	Aluminum/ Boron Carbide	Fiberglass/ polyethylene	Aluminum	2.83
19	Metallic Glass	Metallic Glass	Metallic Glass	2.83
20	Aluminum	Metallic Glass	Aluminum	2.76
21	Aluminum	Lithium polyethylene	Aluminum	2.77
22	Aluminum	Borated polyethylene	Aluminum	2.77
23	Aluminum	Fiberglass/ para-aramid	Aluminum	2.77

MMOD ASSESSMENT: 10-1989 SPE RESULTS



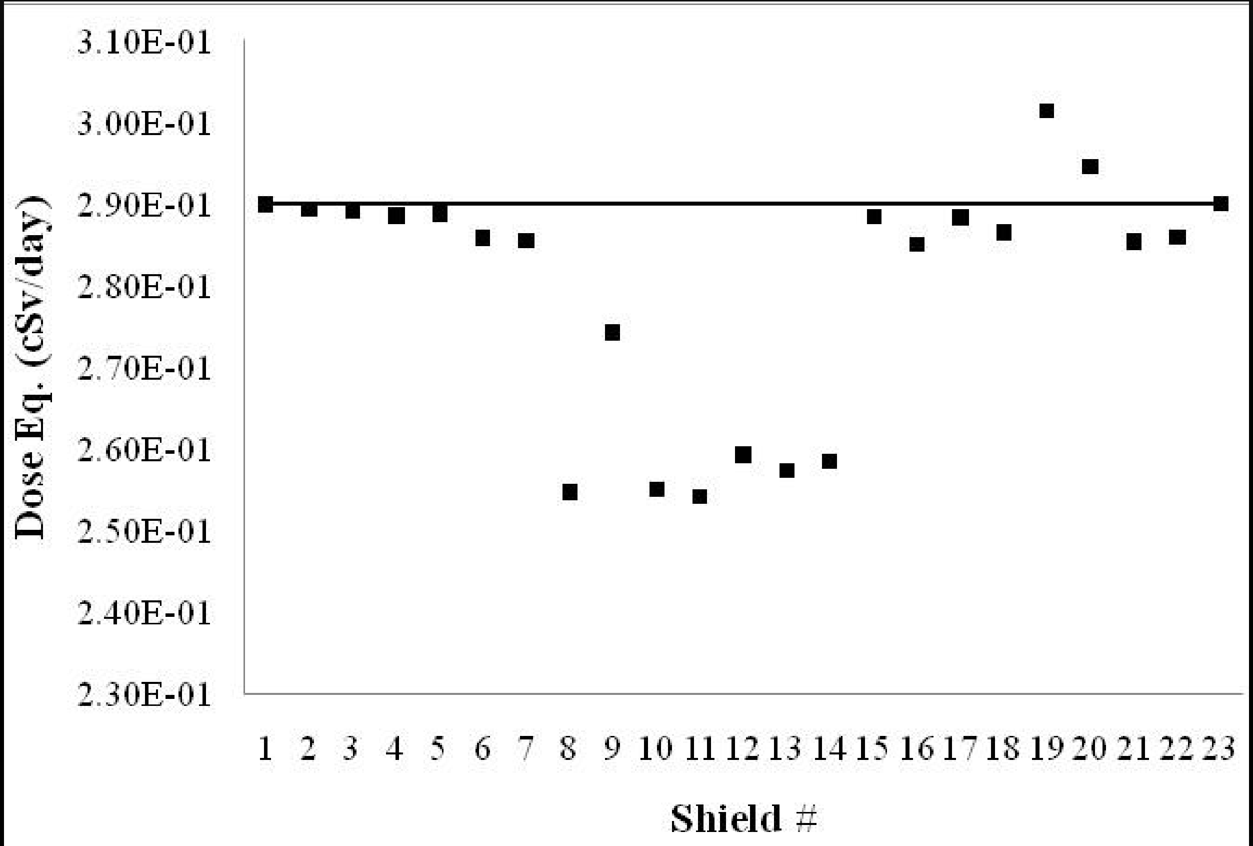
Shield	Dose Eq. (cSv)	% increase/ decrease
1	1.01E+03	0.00%
8	6.14E+02	-39.17%
9	7.39E+02	-26.78%
10	6.15E+02	-39.05%
11	6.06E+02	-39.90%
12	6.84E+02	-32.21%
13	6.58E+02	-34.83%
14	6.75E+02	-33.14%
19	1.31E+03	29.61%
20	1.14E+03	13.02%

MMOD ASSESSMENT: 1982 GCR (MAX) RESULTS



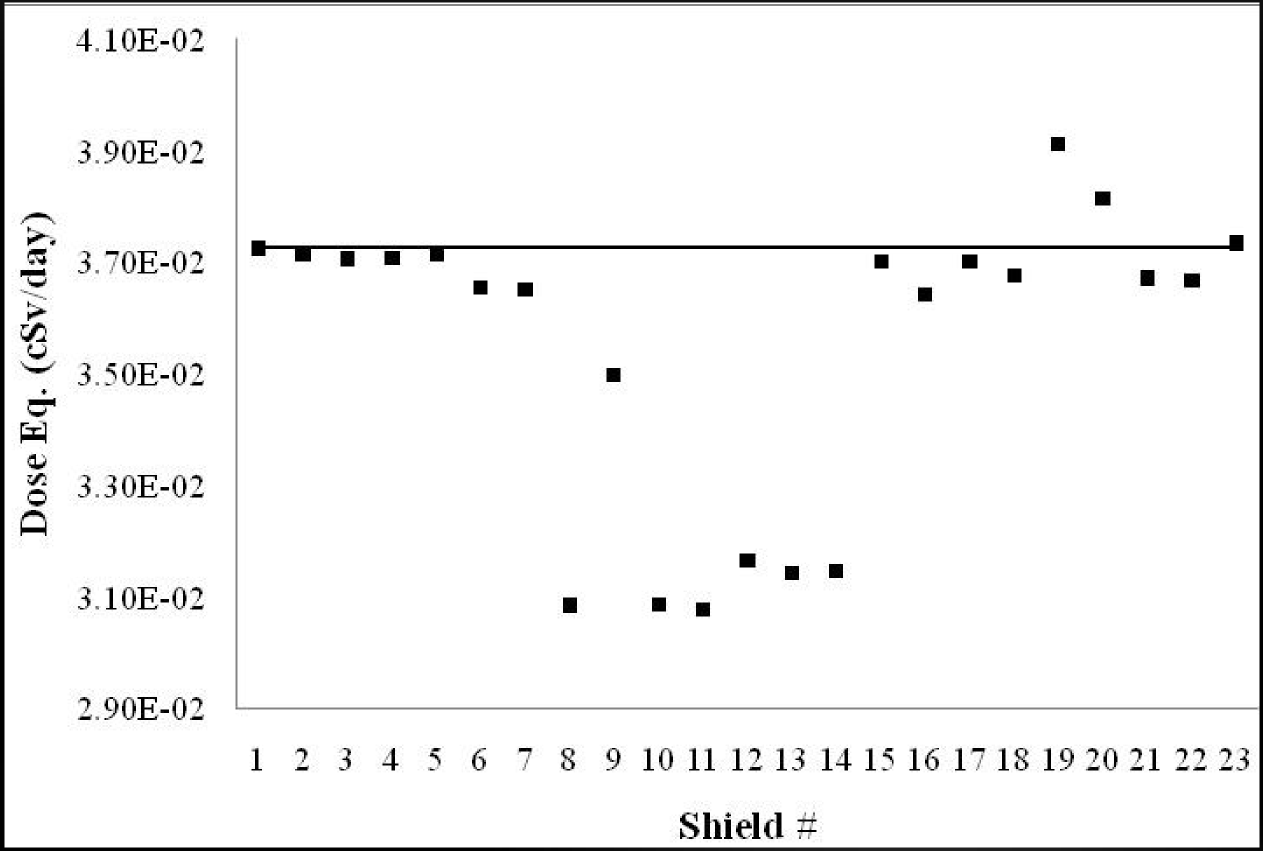
Shield	Dose Eq. (cSv/day)	% increase/ decrease
1	8.62E-02	0.00%
8	7.63E-02	-11.48%
10	7.65E-02	-11.34%
11	7.62E-02	-11.62%
12	7.74E-02	-10.28%
13	7.69E-02	-10.88%
14	7.72E-02	-10.45%
19	9.03E-02	4.69%
20	8.74E-02	1.40%

MMOD ASSESSMENT: 1987 GCR (MIN) RESULTS



Shield	Dose Eq. (cSv/day)	% increase/ decrease
1	2.90E-01	0.00%
8	2.55E-01	-12.16%
10	2.55E-01	-12.06%
11	2.54E-01	-12.35%
12	2.59E-01	-10.61%
13	2.57E-01	-11.26%
14	2.58E-01	-10.87%
19	3.01E-01	3.93%
20	2.95E-01	1.61%

MMOD ASSESSMENT: LEO RESULTS



Shield	Dose Eq. (cSv/day)	% increase/ decrease
1	3.72E-02	0.00%
8	3.09E-02	-17.16%
10	3.09E-02	-17.13%
11	3.08E-02	-17.35%
12	3.17E-02	-15.02%
13	3.14E-02	-15.59%
14	3.15E-02	-15.54%
19	3.91E-02	4.97%
20	3.81E-02	2.37%

MMOD ASSESSMENT: DISCUSSION

- Best performing shields: 8, 10-14
  - Best shield in all environments: 11 (SPE: -40 % , LEO: -17%, GCR: -12%)
- Worst performing shields: 19-20

Shield #	Bumper	Intermediate Layers	Rear Wall	Total Thickness (g/cm^2)
1	Aluminum	ceramic/para-aramid	Aluminum	2.82
8	Aluminum	Polyethylene	Polyethylene	2.8
10	Aluminum	Fiberglass/polyethylene	Polyethylene	2.83
11	Aluminum	Polyethylene	Polyethylene	2.83
12	Aluminum	Boron Carbide	Polyethylene	2.81
13	Aluminum/Boron Carbide	Boron Carbide	Polyethylene	2.86
14	Aluminum	polyethylene	Polyethylene	2.73
19	Metallic Glass	Metallic Glass	Metallic Glass	2.83
20	Aluminum	Metallic Glass	Aluminum	2.76

SUMMARY/CONCLUSIONS

- MLI Assessment
  - Concept MLI improved radiation mitigation properties over Baseline MLI
  - Concept MMOD shield only provided ~5% improvement
    - Need to consider the entire MMOD shield and not just one component
- MMOD Assessment
  - Shields 8, 10-14 were the best radiation mitigators
    - Used materials containing high hydrogen content for intermediate layers and rear wall
  - Shields 19-20 were the worst radiation mitigators
    - Used high-Z, metallic materials

FUTURE RECOMMENDATIONS

- Focus on low-Z materials (high hydrogen content) for intermediate layers and rear walls
- Consider graded-Z configurations
- Use novel bumper materials that remain at the same MMOD performance as the baseline with less material needed, and then backfill that material with low-z materials in the other layers of the shield to increase radiation mitigation performance

THANK YOU

Contact Information:

Kristina Rojdev

kristina.rojdev-1@nasa.gov