Planetary Protection for Europa Mission Instruments

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Overview

- General Specifications
- Bioburden Accounting
  - areas and volumes
  - assays
  - statistics
- Microbial Reduction Prior to Launch
- Estimates of Microbial Reduction in Flight
- Bioburden Record Keeping

General Bioburden Specifications

- PP Specifications
  - Specifications for areas and (non-metallic) volumes not assayed
  - Specifications for microbial reduction (dry heat, hydrogen peroxide vapor (and others TBD)
  - D-values for radiation survival (possibly for spores and vegetatives separately) TBD
- Provided by Project (my opinion)
  - Allowable spore bioburden (if any) for your instrument at Europa contact (past end of mission)
  - Nomograph (or equivalent) of radiation exposure (rads or Grays) at Europa contact vs aluminum (equivalent) shielding thickness NOTE This is the logical opposite of system survivability!

Areas and Volumes

- For spore bioburden estimation prior to any pre-flight microbial reduction
  - assays or PP specifications provide the number of spores per unit surface area
  - PP specifications and infrequently assays on proxy volumes provide the number of spores per unit volume of non-metallic materials
- Therefore the surface areas and volumes must be calculated by the instrument
  - down to the circuit board, component, sensor, wiring and structure level

Areas and Volumes, Example from MRO

High Gain Antenna

HGA Dish Assy Area & Volume Calculations for Planetary Protection				1/16/2003
	Area	Volume		
	cm^2	cm^3	material	
HGA Assy				
Dish Shell (0.25" 1.5pcf korex core, .009" YSH50 Facesheets)				
facesheets	316490	3617	YSH50	
core	329716	419	Korex	
Rings & Ribs (0.25" 1.5pcf korex core, .009" YSH50 Facesheets)				
facesheets	104980	1200	YSH50	
core	109368	139	Korex	
Backshell (0.25" 1.5pcf korex core, .009" YSH50 Facesheets)				
facesheets	78684	899	YSH50	
core	81972	104	Korex	
Subreflector (0.018" YSH50)	3290	75	YSH50	
Subreflector Stiffener (0.024" YSH50)	2594	79	YSH50	
Feed Assy Supt Cone (0.018" YSH50)	8761	200	YSH50	
Feed Assy (Horn, Support Plates, KA & X Band Wave Guides, Disk on Rod)	5045		Al & Copper	
Sub Reflector Composite Support Struts (x6)	3648	934	YSH50	
Non-metallic Total	**1039503**	**7667**		
Metallic Total	**5045**			
Total m^2	**104**			

Areas and Volumes, Example from MRO

HiRise at 2nd Level of Detail

Item ID	Description	Qty	Material	Assembly Level	Exterior S. A. (m^2)	Interior S. A. (m^2)	Internal S.A. (m^2)	Total S.A. (m^2)	Vol (m^3)
Stucture		**1**			**7.444**	**8.187**	**0.000**	**15.630**	**7.52E-03**
573520-506A	Sun Shade Assy	1	Graphite	573520-500	1.146	0.000	0.000	1.146	5.77E-04
573520-502	Telescope Baffle Assy	1	Graphite	573520-500	3.673	0.129	0.000	3.802	1.86E-03
573470-500	Secondary Spider Mount Assy	1	Graphite	573520-500	0.172	0.047	0.000	0.219	5.04E-05
	Secondary Mirror Baffle Assy	1	Graphite		0.195	0.000	0.000	0.195	8.70E-05
	Secondary Mirror Assy	1			0.026	0.008	0.000	0.034	0.00E+00
573520-501A	Metering Structure Assy	1	Graphite	573520-500	0.346	1.330	0.000	1.676	2.94E-04
573431-500	Flexure Assy, Telescope Mount	3	Ti-6Al-4V	573450-500	0.065	0.000	0.000	0.065	0.00E+00
573685-500	Optics Cube Assembly	1	Al/Glass/Ti	573450-500	0.010	0.000	0.000	0.010	0.00E+00
573520-507A	Primary Mirror Baffle Assy	1	Graphite	573460-500	0.303	0.000	0.000	0.303	1.52E-04
573460-500	Primary Mirror Assy	1	Zerodur	573520-500	0.479	0.068	0.000	0.547	0.00E+00
573520-501A	Optics Bench	1	Graphite	573520-500	0.807	3.614	0.000	4.420	2.66E-03
	Focal Plane Assy	1			0.000	1.362	0.000	1.362	2.84E-04
	Focus Mechanism Assy	1			0.000	0.143	0.000	0.143	0.00E+00
573490-500	Tertiary Assy	1			0.000	0.049	0.000	0.049	0.00E+00
573477-500	Lyot Stop Assy	1			0.000	0.119	0.000	0.119	2.37E-04
573520-009A	Field Stop Support Assy	1			0.000	0.049	0.000	0.049	2.13E-04
573480-500	Folding Mirror #1 Asm	1			0.000	0.058	0.000	0.058	3.82E-04
573520-511A	Cover Assy, Optics Bench	1	Graphite	573520-501A	0.147	1.059	0.000	1.206	6.08E-04
573520-512A	Cover Assy, Tertiary Mirror	1	Graphite	573520-501A	0.075	0.152	0.000	0.228	1.14E-04
FPA Electronics		**1**			**0.175**	**0.803**	**0.000**	**0.979**	**1.26E-03**
573666-500	Focal Plane Electronics Housing Assy	1		573668-500	0.175	0.803	0.000	0.979	1.26E-03
Thermal		**M**			**11.422**	**90.080**	**0.000**	**101.503**	**1.40E-03**
573643-500	MLI Assy (Blankets)	16		573430-499	9.832	88.491	0.000	98.323	1.20E-03
301-ASSY	Thermal - TCS	1		573430-500	1.590	1.590	0.000	3.180	2.04E-04
Cabling		**M**			**0**	**0**	**0**	**0**	**0.00E+00**
5738xx	Cabling				0.000	0.000	0.000	0.000	0.00E+00
	HiRISE Totals				**19.041**	**99.070**	**0.000**	**118.112**	**1.02E-02**
Electronics		**2**			**0.795**	**1.944**	**0.000**	**2.740**	**1.06E-03**
573790-500	Power Supply Assy	1		573520-500	0.348	0.884	0.000	1.232	4.72E-04
573700-500	Instrument Electronics Box Asy	1		573520-500	0.447	1.061	0.000	1.508	5.90E-04
	Electronics Totals				**0.795**	**1.944**	**0.000**	**2.740**	**1.06E-03**
					19.836	**101.015**	**0.000**	**120.851**	**1.12E-02**

Assays

- Total and spore bioburden
  - Total bioburden when rinse solution is not heat shocked
  - Spore bioburden when rinse solution is heat shocked (80C for 15 minutes) (needed for dry heat)
  - Vegetative bioburden by subtraction (may be needed for radiation reduction)
- Surface bioburden by swabs or when feasible, wipes
- Bioburden embedded in volume of non-metallic materials
  - By maceration of proxies (trim pieces, typically)
- Surface assays
  - Performed before various closeout levels during assembly (planning required)
- Only sampling, so statistics must be applied
  - wipes on large "flat" surfaces yield better statistics (larger sampling)

Assay Statistics

- Assay data entered into EXCEL spreadsheets for calculation (MER) or calculations done within the assay data base (MSL)
- Estimates calculated of a pooled spore burden density for areas represented by a sampling set (equivalent in sense of parentage)
- Direct calculation of σ for the sampling set

$$\sigma_B = \{\nearrow[N_i - \langle N_i \rangle]^2/(n-1)\}^{1/2} / (f\, A_s)$$

  - straightforward for swabs
    - $\boldsymbol{N_i}$ is the number of spores for the ith swab, $\boldsymbol{n}$ is number of swabs, $\langle \boldsymbol{N_i} \rangle$ is the mean, f is the pour fraction and A_s is the sampled area
    - except use $\sigma_B = 1 / (A_0 f A_s)^{1/2}$ *for all 0 and 1 (A_0 is area rep)*
  - special treatment of wipes (new for MSL)
    - each wipe treated as an equivalent number of standard (25 cm^2, 0.8 pour fraction) swab samples based on the wipe sample area corrected for pour fraction
    - gives full credit to wipes because sample area >> granularity of surface burden spatial distribution
  - neglect sampling area uncertainty and other uncertainties
- Mean burden density plus 3σ is the worst case carried forward in final burden estimate calculations

Microbial Reduction Prior to Launch

- At instrument level
  - at instrument provider discretion
  - documented as part of system level planning
  - if DHMR planned, compatibility required (or for other modalities planned)
  - aseptic integration with flight system capability required because of recontamination
- At flight system level
  - system level DHMR is Project level option/decision
  - if taken, will require instrument level DHMR compatibility

Estimates of Microbial Reduction in Flight

- All my opinion, actual procedure will be established by NASA PPO approved Project PP Plan
- Key is a conservative estimate of microbial reduction due to Jupiter radiation belts
- reduction factor = $10^{-D/D_0}$
  - D is dose for the PP period for the effective shielding of various parts of hardware (at the area and volume level)
    - based on information supplied by Project
    - if omnidirectional, divide by π for 1-d conservatism
    - use maximum "shielding" in direction away from spacecraft
    - convert other materials to Al equivalent by density ratio (to Al) and atomic number ratio (to Al) as approximation (use C for polymers)
  - D_0 two D-values, one for spores and one for vegetatives
    - from NASA PPO
    - there may be a max reduction factor for vegetatives if NASA PPO sets a radiation resistant subpopulation of vegetatives

Bioburden Record Keeping

- An active electronic spreadsheet or equivalent
  - record of current best estimate of instrument's bioburden
  - linked to lower level data sources in order to automatically accommodate updates to the relevant data
- Required data at level of assay groups (sampling sets)
  - internal, external surface areas, non-metallic volumes
  - internal, external surface bioburden (assay or spec)
  - embedded bioburden (spec or assay)
  - bioburdens above post instrument level microbial reduction (if any)
  - bioburdens above post system level DHMR (if any)
  - max aluminum-equivalent shielding thickness
  - bioburdens above post radiation reduction

Bioburden Record Keeping

MRO

Item Description By Subsystem	Manufacturing Environment preATLO (internal assembly)	ITEM Exterior Surface Area (m^2)	ITEM Total Surface Area (m^2)	INT Surface Bio Burden	Non-Metal Volume (cm^3)	Original Bioburden Total	Standard Process Remediation/PP Reduction	Exempt via B&B Analysis	B&B Adjusted Bioburden	% total req	Exempt via B&B Analysis	B&B Adjusted Bioburden	% total req

EJSM conceptual

Instrument name

Assay Group Description	Mfr Environment (internal assembly)	ITEM Exterior Surface Area (m^2)	ITEM Total Surface Area (m^2)	INT Surface Bio Burden	EXT Surface Bio Burden	Non-Metal Volume (cm^3)	Embedded Bioburden	Microbial Reduction Process	Reduced Bioburden INT	Reduced Bioburden EXT	Reduced Bioburden Embedded	••••

••••	Al equiv shielding, cm INT	Al equiv shielding, cm EXT	Al equiv shielding, cm Embedded	Rad Reduced Bioburden EXT	Rad Reduced Bioburden Embedded	Rad Reduced Bioburden INT	Rad Reduced Bioburden EXT	Rad Reduced Bioburden Embedded	Final Bioburden

- If System level DHMR option taken by Project, three more fields for internal surface, external surface, and embedded burden post DHMR required
- If vegetative bioburden requirements, an additional row for each component required