1. REPRODUCING DOSE RESPONSE FUNCTIONS

We are trying to gain confidence in our ability to model the dose calculated using SPENVIS and the GRAS tools it includes. We have tried to reproduce the methods and results presented in TEC-EES/2011.812/GS ("Simulation of dose response functions for Jupiter missions") by G. Santin & M. Ansart, but have encountered problems.

First, we tried to reproduce the simple Shieldose results shown in Table 2 of the Santin & Ansart note (Column 2: "Solid Sphere SHD2"). The initial steps taken are:

1) Use the orbit generator to set up an equatorial orbit with semimajor axis of Ganymede, i.e. 1,070,400 km (~15 RJ), eccentricity = 0, for a duration of 310 days. See attached **orbit_report.html** for the summary file.
2) Calculate JOSE model fluxes run for this orbit, using mean flux, JPL HIC equatorial model for heavy ions, and MAX (Jose, IEM background) flux. 100 cm**2/s/sterad flux for electrons and protons. See attached **jorem_fluxes.html** for the summary file.
3) Run SHIELDOSE-2Q for the centre of solid Al spheres with Si target material. See attached **shieldose2q.html** for the summary file.

As shown in the attached output report **shieldose2q.html**, our doses for this simple calculation are significantly lower than the level reported in the note – i.e.

5 mm shielding: 617 krad (Santin & Ansart: 1016 kRad)
10 mm shielding: 181 krad (Santin & Ansart: 266 kRad)
20 mm shielding: 45 krad (Santin & Ansart: 62 kRad)

(Note that we have also tried this calculation with an uploaded trajectory file extracted from the SPICE kernel provided in the AO package, for the Ganymede phase of the mission. The resulting doses are very similar to the ones we obtain using the orbit generator.)

Question 1. Why are our Shieldose results so different to those in the technical note?

We then tried to reproduce the doses in the more realistic "Box" and "Sphere" columns of Table 2 using GRAS in SPENVIS. However, it does not seem possible to use the SPENVIS version of GRAS in the way described in the note (which used a standalone installation of GRAS). For example, in SPENVIS there does not seem to be a way of changing the detector size, shape or construction (i.e. making it a hollow sphere of finite size and thickness). Only the position can be changed in the Geometry Definition. Nevertheless we tried to reproduce the results of the Sphere column, using the following steps.

1. Using the online Geometry Definition page, I set up a model with a 1.5 m radius, 5 mm thick Al spherical shell, in the centre of which is a 5 cm radius, 10 um thick Si shell, and set the detector in the middle of this (see the attached **geometry_report.html**, and the gdml model itself, **spheres.gdml**).
2. Using GRAS in "GDML" execution mode, the Source Particles were set to Trapped, e-. Source geometry is set to type "sphere", centred at (0m, 0m, 0m) with a radius of 2 metres.
3. Only simulations with 10,000,000 particles produced non-zero dose results in the Si sphere. The fluence report showing results FROM Al and TO Si (**10million_fluence_spheres.csv**) and the dose report (**10million_dose_spheres.csv**) are attached, along with the corresponding macros **10million_fluence_spheres.g4mac** and **10million_dose_spheres.g4mac**. We believe that the low number of electron entries into the Si sphere (10) is broadly consistent with the number leaving the outer Al sphere (1.04×10^6), since after encountering the Al shell, primary and secondary particles scatter into 2pi steradians, and the inner Si sphere subtends a solid angle of approx 3.5×10^{-5} steradians → $1.04 \times 10^6 \times 3.5 \times 10^{-5} / 2\pi = 5.8$. However, we are unsure about interpretation of the DOSE SPECTRUM data.

Question 2. How do we interpret the dose data for the Si sphere? The statistics are clearly poor even with 10,000,000 particles in the simulation, and the results do not appear to match those of Santin & Ansart. Is this a statistical limitation, or is there something more fundamental that we are doing wrong?

Question 3. In the dose file, there is a spread of events in the DOSE vs PRIMARY KINETIC ENERGY table. But why do all of these events occupy the first bin in the DOSE SPECTRUM table? Would we not expect a small spread in the dose energies?

Question 4. What is the most appropriate source geometry to use in this case? We find that the results are extremely sensitive to the position and type of source used in the simulation. The source spectrum is discussed by Santin & Ansart, but the authors do not state what source geometry they used.

Question 5. Is it necessary to use the standalone version of GRAS to reproduce the calculations in the Santin & Ansart note?

2. USING STAND-ALONE GRAS INSTALLATION

We understand that for accurate assessment of shielding requirements and dose, large numbers of particles are often required in the simulation. The results of our dose calculation above seem to suggest that even 10 million particles (the maximum possible in the SPENVIS version) is sometimes too small, and so it is necessary to use a standalone version of GRAS to run the models locally. We have tried to do this; our installation is GRAS v. 3.1 (from the GRAS website at http://spitfire.estec.esa.int/trac/GRAS/) with Geant4.9.5.p01 (from the Geant4

website at http://geant4.web.cern.ch/geant4/support/download.shtml). Compilation of these codes was successful, gdml was included, and the example files supplied with the source code appear to work.

However, when running the SPENVIS-generated macros in our local installation, we obtain zero fluence and dose outputs. For example, we ran the fluence and dose macros for the Al and Si sphere example above, on our local installation, to compare to the SPENVIS output. Although the simulation ran without errors reported, all of the tables were filled with zeros – zero fluence and zero dose reported. (Note that when running locally, we rename the gdml model to "spenvis_gdm.gdml", and the log output confirms that the model has been read.)

*We did not save the 10 million particle local output files to show you. To save time we have re-run the fluence calculation for 1 million particles on the local installation, and have attached the.csv, macro and log file file for the run (**1million_fluence_sphere_LOCAL.csv, .g4mac and .log** attached). Note that in SPENVIS, the resulting fluence is non-zero (**1million_fluence_sphere_SPENVIS.csv** attached.)*

We submitted a query on the SPENVIS forum and received a reply (see thread at http://www.spenvis.oma.be/forum/viewtopic.php?f=27&t=228). Making the changes suggested in the response has not solved the problem.

Question 6. Can you suggest a solution to the zero result problem for local GRAS runs?). This seems critical since we need to run locally to access the high particle numbers needed for accurate estimation of dose.

3. VALIDITY OF INSTRUMENT MODEL OUTPUTS

We have constructed a GDML model of our instrument (attached as **INSTRUMENT_V4.gdml**) and calculated the fluence to the various elements in the instrument, in SPENVIS, with 10,000,000 particles in the simulation (macro **INSTRUMENT_fluence.g4mac**). The results (shown in **INSTRUMENT_fluence.csv**) indicate that no electrons reach V3 (fluence6). Since we are unable to run a local GRAS simulation to increase the number of particles, we cannot check whether this is a limitation of the statistics or whether it indicates a problem with the calculation.

Although there are surrounding structures which provide some shielding of V3, sector shielding analysis shows that there is a substantial portion of the instrument where very little shielding is present (2 mm Al – just the outer casing of the instrument itself). Yet the zero fluence of electrons at V3 suggests that no additional shielding is required, which cannot be correct.

Question 7. We would appreciate your inspection of the model and macro; is there an error in our setup, or is there another explanation for the zero fluence indicated at V3?