On-Line Tool for Assessing Radiation In Space Verification and Validation Effort Using STS DLOC and ISS TEPC Measurements

March 29, 2010

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The Space Radiation Analysis Group is in the process of providing verification and validation efforts for the On-Line Tool for Assessing Radiation In Space (OLTARIS). The effort was outlined in a preliminary plan created in June of 2006. This report provides both passive and active measurement comparisons for OLTARIS results, and provides feedback on the user interface for OLTARIS. The process consists of inputing the appropriate mission information, such as begin and end dates, as well as specifying the environmental conditions used in the calculations and the desired response functions for output.

Fractional days were accepted into the OLTARIS input, however the beginning and ending times for a mission could not be specified. Entering a start date and the actual mission duration in fractional days is possible, but without the ability to specify a start time, the end date may not be correct. This implies that time periods are assumed to start at 00:00 on the start date. As a result, there is the possibility that some SAA or high latitude passes may be omitted or erroneously included.

According to the *Plan for Integrated V&V of ESMD Integrated Radiation Design Analysis Toolset - Phase I*, dated 6/2006, there are multiple OLTARIS parameters which are to be compared with measurement data. These include STS and ISS TEPC information, as well as various versions of Passive Dosimeter data. The OLTARIS tool has an option to include TEPC response in the output data. For this iteration of the report, thickness distributions were produced for ISS TEPC locations and for Space Transport System (STS) DLOC Radiation Area Monitor (RAM) locations.

Using a Perl script provided by LaRC, SRAG was able to translate its shield files for the Space Transportation System (STS) into thickness distributions usable by OLTARIS. The STS airlock has two configurations, inside the cabin ('in") or moved out into the payload bay ("out"). Shield files exist for both configurations. For the two ISS missions included in the V&V plan, the airlock was verified to be in the "out" configuration The remaining missions did not fly to ISS and were assumed to have used the airlock "in" configuration. The airlock configuration was verified for the missions when documentation was available (press kits or mission information packages), however, not all missions had this information available.

The assembly stage of the ISS was reproduced as appropriate for the mission cases using available CAD models with the Shuttle docked. Dose points were chosen to approximate the location of the ISS TEPC for these cases. Shield files were produced using I-DEAS 11 and the Barrier Thickness Evaluation (BTE) ray tracing application [1]. The LaRC Perl script was again used to translate SRAG shield files into thickness distributions for use within OLTARIS.

The thickness distributions were then used within OLTARIS to produce the data tabulated and charted below. The DLOC2 data set presented in a previously submitted report utilized a shield file included in

OLTARIS and was not translated to XML format by SRAG. Comparison of the previously run DLOC2 data to the DLOC2 data included in this report shows that there is no significant difference between the two data sets. This similarity in data for identical locations using different methods of XML file generation would imply that the shield file to thickness distribution translation done by SRAG was carried out as expected, and no additional error based upon thickness distribution translation has propagated into the results.

Visual inspection of the XML files was also performed, and no significant errors were detected. Of note, however, is that the coordinates for the location supplied in the SRAG shield files were not included in the target coordinates within the thickness distribution XML file. (target_x, target_y, and target_z are all set to .0000E+00 within the thickness_set header). The coordinates given in the SRAG shield files for DLOC locations use the Space Shuttle Coordinate System [2]. The lack of thickness_set header coordinates was not viewed as a significant issue for concern since all thickness distributions were used independently of one another. The issue is noted in case there are plans to use multiple thickness distributions at a later point, as the XML structure indicates.

The online tool does include documentation to create Thickness Metafiles, but these files must be in a specific XML format. This process could be simplified and could reduce the possibility for user error by allowing plain text shield file input, and providing a conversion utility during upload. Specifying a standard plain text format and using a consistent translation process would provide a more streamlined user experience.

With regard to future work in analyzing SPE events, issues exist with the SPE events defined in the V&V Plan as described below for each event:

"Halloween Storm" Data
TEPC data is unavailable for comparison. The ISS TEPC was failed during the event and no data was recorded during that time period. The January 2005 SPE will be used in place of this event. The January 2005 event is a well known event, and there is TEPC data coverage. Due to orbital phasing, however, the dose measured on ISS was minimal.

Selection of SPE for "TBD SPE"
The event which occurred on November 22, 2001 will be used as the TBD SPE specified in the IV&V plan. This event has ISS TEPC data available for comparison, and of the events with complete TEPC data coverage, it has the largest dose measured.

Additional Input
The OLTARIS 'Show Results' page has a very useful interactive layout with respect to the plots, however it would also be useful to download the entire data set. All output sections, including the 'mission totals', 'project summary' and raw data for the charts, should be in a format that can be imported into analysis software. This would minimize translation errors when using data externally. The envisioned implementation of this would be a .zip file that includes comma separated value files for each section as well as for each data file included in the OLTARIS results. In addition, the 'project summary' information would be useful to have at the top of the 'Show Results' page, in order to more easily differentiate between job results when performing multiple data runs.

The Environments portion of the Project Summary listing was found to have an issue. If the environment is defined without including the Neutron Albedo (unchecked box), but also requesting the

Environment Flux to be saved, the resulting project summary section shows that the environment saved option was not selected. If this is the expected behavior, a note should be included for the user to reference.

The ISS locations were run for both environments with and without neutron albedo included. In both cases, altitude information for ISS related analysis was taken from the as-flown altitude profile for the appropriate dates. For the STS-114 case, ISS TEPC data was unavailable for the first 2 days of the mission. OLTARIS mission input was modified to reflect this lack of data by adjusting mission duration to match the time period that valid measurement data exists. This allowed for appropriate comparison of OLTARIS output to measurements. Comparison of the results show the two environments produce similar data, which is consistent with expected behavior.

Summary and Conclusions

Overall, the OLTARIS input functions performed as expected and provided methods for project setup, environment definition, comments, and submission of the projects for analysis, except as noted previously for the isolated case of an environment defined without neutron albedo. The interface for viewing output also performed as expected. No other issues were found with the functionality of the tool's user interface, though some improvements are possible.

Percent difference was generated by subtracting OLTARIS calculation results from measured data and dividing by the measured data. A negative percent difference indicates overestimation of dose by OLTARIS. Percent difference is not included in the charts, but the tabular data shows the relevant information.

The lack of time inputs when using fractional days within the tool may cause inaccuracies in representation of dose by OLTARIS due to additional time being included in the mission duration. In addition, the lack of start and stop times for mission, along with the use of a circular orbit, further skews results away from measured data.

CAD model fidelity is also a factor that should not be overlooked. While efforts were made to approximate the ISS configuration as closely as possible, there are still inherent configuration issues included in any station model due to equipment location and other real time changes that will affect mass distribution within the vehicle.

Both TEPC and TLD-100 calculations in OLTARIS, as compared to the corresponding instrument measurements, show trending in accordance with measured data. Variances between measured data and calculated results could be reduced by adjusting mission input parameters to more closely match vehicle timing and trajectory as flown.

Estimated values from the tool when using the TLD-100 Response Function tend to over-predict the dose in most cases. OLTARIS predicted values using the TEPC Response Function, however, are low relative to measurement. Both may require additional adjustment to approach measured results. With additional focus on removing uncertainties within orbital trajectory and mission timing, the OLTARIS system is expected to improve with respect to accuracy of results as measured on-orbit.

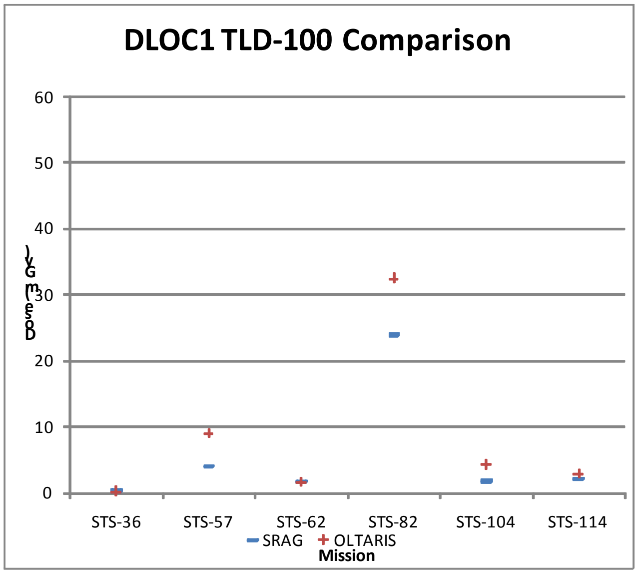
As the tool exists currently, the trends between OLTARIS outputs are consistent with one another and trend in the same manner as measurements. However, the tool yields results that differ from measured values by 35% to 75% for TEPC response. Also, while OLTARIS passive dosimeter (TLD-100) response tends to be closer to measured values than the TEPC response, the results still vary from measured values by as much as 160%. Dose estimates fall within a reasonable range compared to measurement, but significant uncertainties still exist within the trapped estimates. In light of this, the conclusion is that the tool is ready for comparative trending usage.

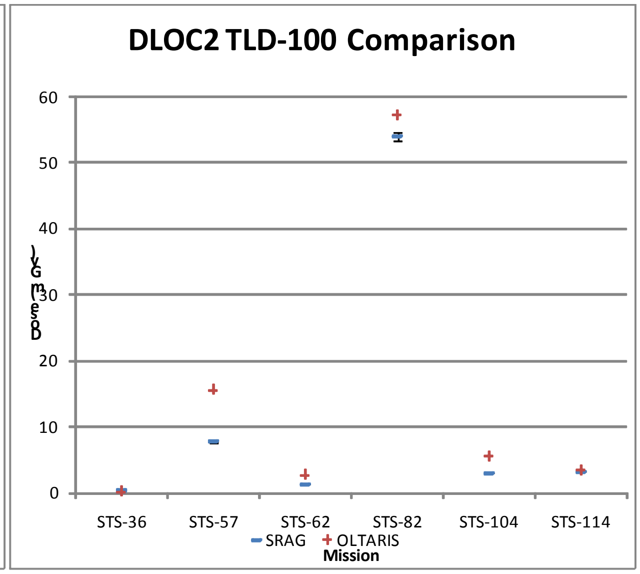
References

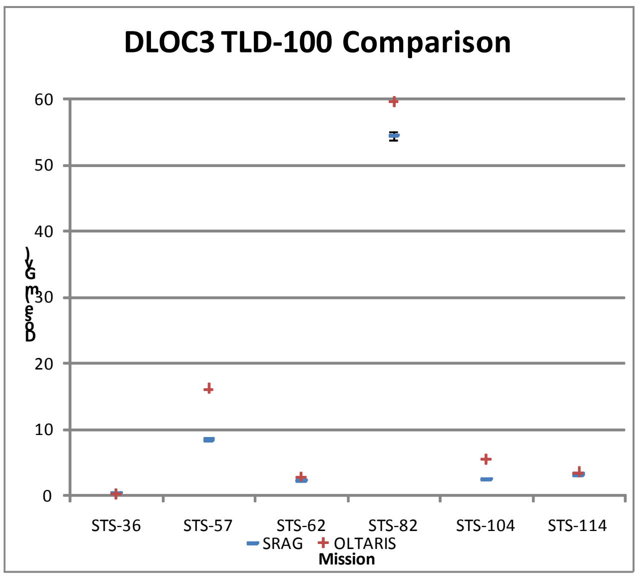
[1] Barrier Thickness Evaluation application, version 2.2
EDS PLM Solutions, 2002

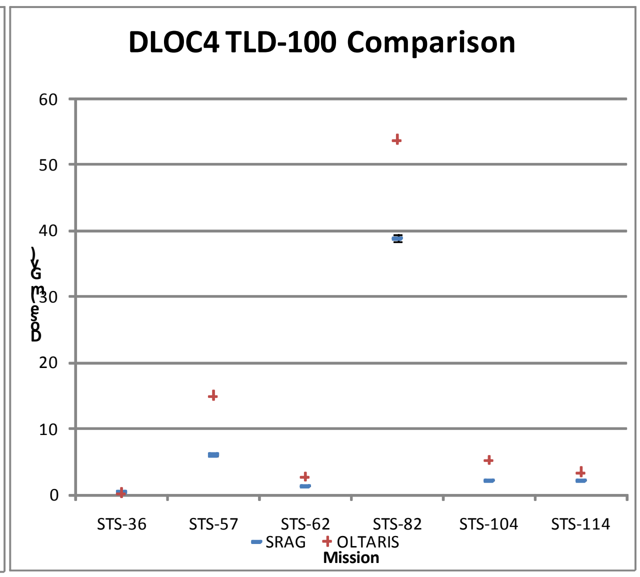
[2] *Space Shuttle Coordinate System*
http://spaceflight.nasa.gov/shuttle/reference/shutref/coord/

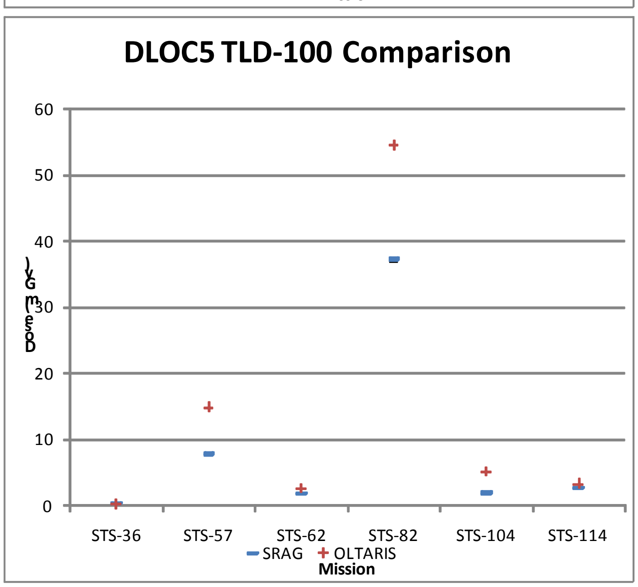
Summary STS measurement by location -- Comparison of TLD-100

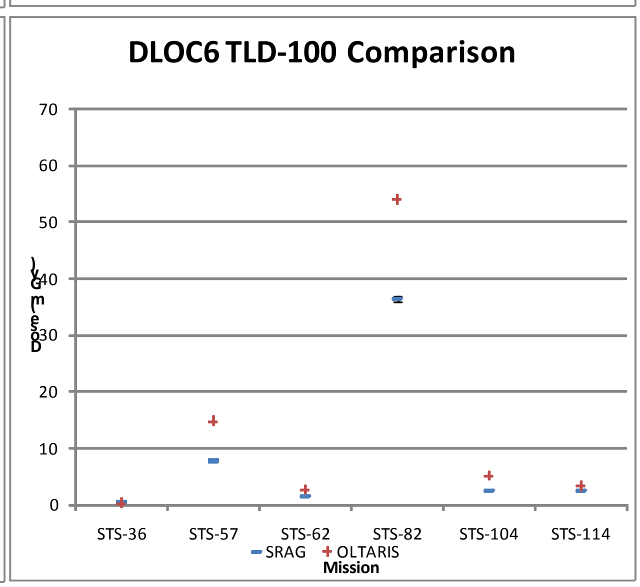




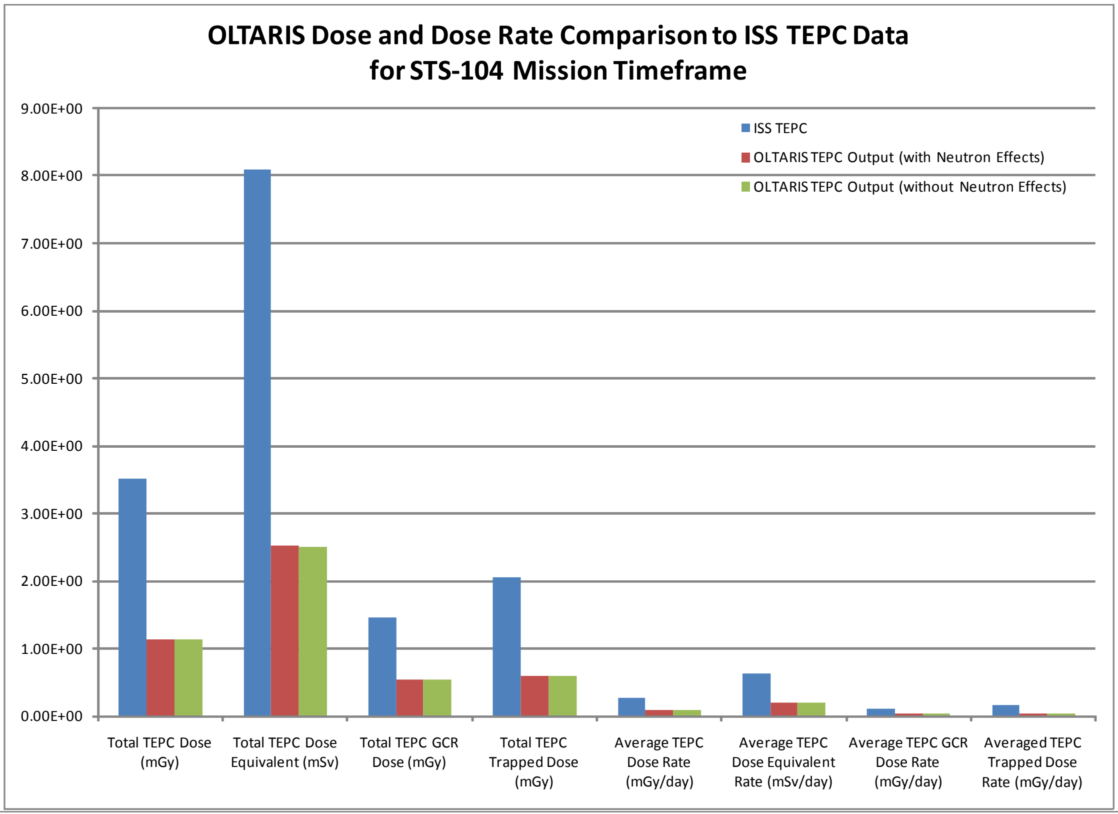


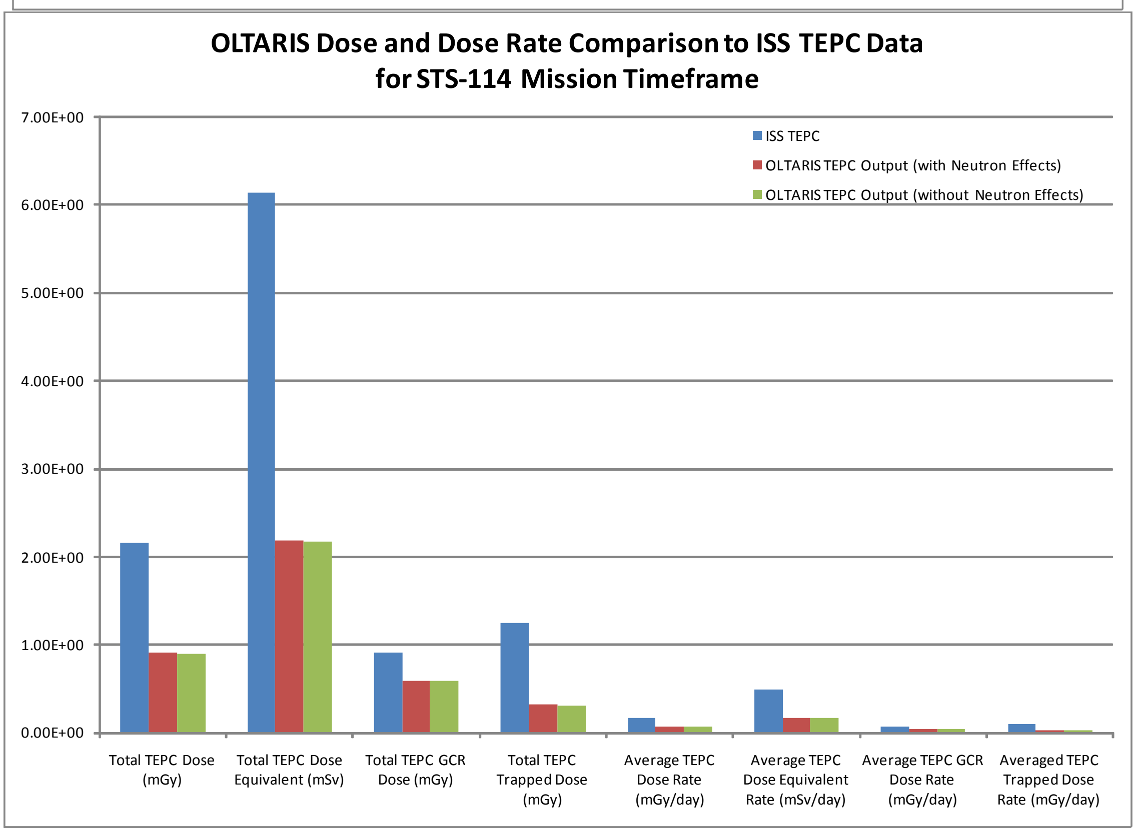






Summary ISS TEPC Data Summary for Corresponding ISS TEPC Data





Tabulated Data Summary for DLOC Locations

Mission	Dosimeter Measurement Data by Location (TLD-100)												Units
	DLOC1	+/-	DLOC2	+/-	DLOC3	+/-	DLOC4	+/-	DLOC5	+/-	DLOC6	+/-	
STS-36	0.346	0.005	0.335	0.005	0.329	0.005	0.345	0.004	0.347	0.006	0.355	0.007	mGy
STS-57	3.996	0.033	7.738	0.068	8.516	0.097	6.004	0.077	7.849	0.049	7.791	0.062	mGy
STS-62	1.627	0.019	1.285	0.013	2.275	0.022	1.325	0.020	1.800	0.020	1.417	0.020	mGy
STS-82	23.950	0.150	54.010	0.610	54.460	0.640	38.830	0.510	37.340	0.330	36.390	0.400	mGy
STS-104	1.770	0.030	3.020	0.040	2.510	0.050	2.130	0.080	1.940	0.080	2.400	0.050	mGy
STS-114	2.130	0.020	3.220	0.040	3.220	0.020	2.170	0.040	2.730	0.030	2.500	0.030	mGy

Mission	Dosimeter Calculation Data by Location (TLD-100 Response Function)						Units
	DLOC1	DLOC2	DLOC3	DLOC4	DLOC5	DLOC6	
STS-36	2.00E-01	1.88E-01	1.86E-01	1.89E-01	1.88E-01	1.89E-01	mGy
STS-57	8.99E+00	1.56E+01	1.62E+01	1.50E+01	1.49E+01	1.48E+01	mGy
STS-62	1.61E+00	2.69E+00	2.79E+00	2.61E+00	2.60E+00	2.59E+00	mGy
STS-82	3.24E+01	5.72E+01	5.96E+01	5.38E+01	5.45E+01	5.40E+01	mGy
STS-104	4.27E+00	5.53E+00	5.47E+00	5.16E+00	5.11E+00	5.06E+00	mGy
STS-114	2.88E+00	3.43E+00	3.49E+00	3.33E+00	3.29E+00	3.26E+00	mGy

Mission	Difference in result by Location (Measured - Calculated)						Units
	DLOC1	DLOC2	DLOC3	DLOC4	DLOC5	DLOC6	
STS-36	1.46E-01	1.48E-01	1.43E-01	1.56E-01	1.59E-01	1.66E-01	mGy
STS-57	-5.00E+00	-7.82E+00	-7.64E+00	-8.96E+00	-7.01E+00	-6.96E+00	mGy
STS-62	1.30E-02	-1.41E+00	-5.14E-01	-1.29E+00	-7.99E-01	-1.17E+00	mGy
STS-82	-8.48E+00	-3.20E+00	-5.10E+00	-1.49E+01	-1.72E+01	-1.76E+01	mGy
STS-104	-2.50E+00	-2.51E+00	-2.96E+00	-3.03E+00	-3.17E+00	-2.66E+00	mGy
STS-114	-7.51E-01	-2.07E-01	-2.74E-01	-1.16E+00	-5.57E-01	-7.64E-01	mGy

Mission	Percent Difference in result by Location (wrt Measurement)					
	DLOC1	DLOC2	DLOC3	DLOC4	DLOC5	DLOC6
STS-36	42.1%	44.0%	43.3%	45.2%	45.7%	46.9%
STS-57	-125.0%	-101.1%	-89.8%	-149.2%	-89.3%	-89.3%
STS-62	0.8%	-109.3%	-22.6%	-97.3%	-44.4%	-82.4%
STS-82	-35.4%	-5.9%	-9.4%	-38.4%	-46.0%	-48.3%
STS-104	-141.2%	-83.1%	-117.9%	-142.3%	-163.4%	-110.8%
STS-114	-35.3%	-6.4%	-8.5%	-53.6%	-20.4%	-30.6%

Tabulated Data Summary for ISS TEPC Locations

	STS 104 (ISS 2) ISS TEPC Measurement to OLTARIS Comparison		
	ISS TEPC	OLTARIS TEPC Output (with Neutron Effects)	OLTARIS TEPC Output (without Neutron Effects)
Total Dose (mGy)	-	1.61E+00	1.60E+00
Total TEPC Dose (mGy)	3.51E+00	1.15E+00	1.14E+00
Total TEPC Dose Equivalent (mSv)	8.08E+00	2.52E+00	2.51E+00
Total TEPC GCR Dose (mGy)	1.46E+00	5.49E-01	5.49E-01
Total TEPC Trapped Dose (mGy)	2.05E+00	5.97E-01	5.95E-01
Average Dose Rate (mGy/day)	-	1.26E-01	1.25E-01
Average TEPC Dose Rate (mGy/day)	2.77E-01	8.97E-02	8.95E-02
Average TEPC Dose Equivalent Rate (mSv/day)	6.37E-01	1.97E-01	1.96E-01
Average TEPC GCR Dose Rate (mGy/day)	1.15E-01	4.30E-02	4.30E-02
Averaged TEPC Trapped Dose Rate (mGy/day)	1.62E-01	4.68E-02	4.66E-02
	STS 104 (ISS 2) Percent Difference from ISS TEPC Measurement		
	ISS TEPC	OLTARIS TEPC Output (with Neutron Effects)	OLTARIS TEPC Output (without Neutron Effects)
Total TEPC Dose (mGy)		67.4%	67.5%
Total TEPC Dose Equivalent (mSv)		68.8%	69.0%
Total TEPC GCR Dose (mGy)		62.4%	62.4%
Total TEPC Trapped Dose (mGy)		70.9%	71.0%
Average TEPC Dose Rate (mGy/day)		67.6%	67.6%
Average TEPC Dose Equivalent Rate (mSv/day)		69.0%	69.2%
Average TEPC GCR Dose Rate (mGy/day)		62.7%	62.7%
Averaged TEPC Trapped Dose Rate (mGy/day)		71.1%	71.2%

	STS 114 (ISS 11) ISS TEPC Measurement to OLTARIS Comparison		
	ISS TEPC	OLTARIS TEPC Output (with Neutron Effects)	OLTARIS TEPC Output (without Neutron Effects)
Total Dose (mGy)	-	1.29E+00	1.28E+00
Total TEPC Dose (mGy)	2.17E+00	9.07E-01	9.03E-01
Total TEPC Dose Equivalent (mSv)	6.14E+00	2.19E+00	2.17E+00
Total TEPC GCR Dose (mGy)	9.16E-01	5.85E-01	5.85E-01
Total TEPC Trapped Dose (mGy)	1.25E+00	3.22E-01	3.18E-01
Average Dose Rate (mGy/day)	-	1.03E-01	1.02E-01
Average TEPC Dose Rate (mGy/day)	1.73E-01	7.25E-02	7.22E-02
Average TEPC Dose Equivalent Rate (mSv/day)	4.91E-01	1.75E-01	1.74E-01
Average TEPC GCR Dose Rate (mGy/day)	7.32E-02	4.68E-02	4.68E-02
Averaged TEPC Trapped Dose Rate (mGy/day)	9.99E-02	2.58E-02	2.54E-02
	STS 114 (ISS 11) Percent Difference from ISS TEPC Measurement		
	ISS TEPC	OLTARIS TEPC Output (with Neutron Effects)	OLTARIS TEPC Output (without Neutron Effects)
Total TEPC Dose (mGy)		58.1%	58.3%
Total TEPC Dose Equivalent (mSv)		64.4%	64.7%
Total TEPC GCR Dose (mGy)		36.1%	36.1%
Total TEPC Trapped Dose (mGy)		74.2%	74.6%
Average TEPC Dose Rate (mGy/day)		58.1%	58.3%
Average TEPC Dose Equivalent Rate (mSv/day)		64.4%	64.7%
Average TEPC GCR Dose Rate (mGy/day)		36.1%	36.1%
Averaged TEPC Trapped Dose Rate (mGy/day)		74.2%	74.6%

OLTARIS Input Information

STS-36

Environment Type: Earth-Circular Orbit
Mission Start Date: 1990-02-28
Mission End Date: 1990-03-04
Mission Duration: 4.0 days
Altitude: 226 km
Inclination: 62.0
GCR, Neutron Albedo, and Trapped Protons Included
TLD-100 Thickness Distribution File: STS_dloc1.xml (968 rays) through STS_dloc6.xml (968 rays)

STS-57

Environment Type: Earth-Circular Orbit
Mission Start Date: 1993-06-21
Mission End Date: 1993-07-01
Mission Duration: 10.0 days
Altitude: 470.0 km
Inclination: 28.5
GCR, Neutron Albedo, and Trapped Protons Included
TLD-100 Thickness Distribution File: STS_dloc1.xml (968 rays) through STS_dloc6.xml (968 rays)

STS-62

Environment Type: Earth-Circular Orbit
Mission Start Date: 1994-03-04
Mission End Date: 1994-03-18
Mission Duration: 14.0 days
Altitude: 302 km
Inclination: 39.0
GCR, Neutron Albedo, and Trapped Protons Included
TLD-100 Thickness Distribution File: STS_dloc1.xml (968 rays) through STS_dloc6.xml (968 rays)

STS-82

Environment Type: Earth-Circular Orbit
Mission Start Date: 1997-02-11
Mission End Date: 1997-02-21
Mission Duration: 10.0 days
Altitude: 667 km
Inclination: 28.45
GCR, Neutron Albedo, and Trapped Protons Included
TLD-100 Thickness Distribution File: STS_dloc1.xml (968 rays) through STS_dloc6.xml (968 rays)

STS-104 / ISS-2

Environment Type: Earth-Circular Orbit
Mission Start Date: 2001-07-12
Mission End Date: 2001-07-24
Mission Duration: 12.77 days

Altitude: 395.0 km
Inclination: 51.6
GCR and Trapped Protons Included
Neutron Albedo as specified in results
ISS TEPC Thickness Distribution File: ISS-7A-SM327_approx_w-STS-alum.xml (968 rays)
TLD-100 Thickness Distribution File: STS_dloc1_airlk_out.xml (968 rays) through STS_dloc6_airlk_out.xml (968 rays)

STS-114 / ISS-11

Environment Type: Earth-Circular Orbit
Mission Start Date: 2005-07-26 (2005-07-26)
Mission End Date: 2005-08-09
Mission Duration: 13.9 days (12.51 days)
Altitude: 355.0 km
Inclination: 51.6
GCR and Trapped Protons Included
Neutron Albedo as specified in results
ISS TEPC Thickness Distribution File: ISS-LF1-atSM327_approx_wSTS-alum.xml (968 rays)
TLD-100 Thickness Distribution File: STS_dloc1_airlk_out.xml (968 rays) through STS_dloc6_airlk_out.xml (968 rays)
Note: Actual mission start date modified for ISS TEPC runs due to lack of ISS TEPC data on 7-26 and 7-27. Adjusted parameters are noted in brackets and reflect parameters used for ISS TEPC projects.