Debris Assessment Software
Operator's Manual

Version 1.5

Space and Life Sciences Directorate
Earth Science and Solar System Exploration Division
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Orbital Debris Program Office

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Debris Assessment Software Operator's Manual Version 1.5

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DEBRIS ASSESSMENT SOFTWARE (VERSION 1.5)
OPERATOR'S MANUAL

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1. INTRODUCTION TO THE DEBRIS ASSESSMENT SOFTWARE (VERSION 1.5)

The Debris Assessment Software (DAS) has been developed to assist NASA programs in performing orbital debris assessments as described in NASA Safety Standard 1740.14, "Guidelines and Assessment Procedures for Limiting Orbital Debris." The software follows the structure of the standard and provides the user with tools to ensure compliance with the guidelines or to assess debris mitigation options to bring a program within guidelines.

This operator's manual acquaints the user with the overall features of the software, without detailing all of the options presented by the software. Because the software has a rather complex structure, a detailed operator’s manual would make it difficult to relate the various parts of the analysis support. In an attempt to alleviate this problem the software has some on-line user help.

To help the user, this document has two appendices that address the installation and the mechanics of the use of the software. Appendix A provides instructions for installing the software system on the user's computer, by using either a floppy disk provided with this operator’s manual or by downloading the DAS system from the Internet. Appendix B provides a summary of the program screen structure and the format for user interaction with the program.

1.1 Requirements for the DAS Runtime Environment

DAS runs in a Microsoft Windows environment. The expanded directory requires about 10 Megabytes of storage space on the hard disk and the program itself is 5 Megabytes in size. The DAS display will not work properly if your display color settings are set to 16 or 256 colors. Increase the number of colors to a higher number such as “High Color” or “True Color”.

The original DAS 1.0 was a DOS program; the new 1.5 version is a Windows program though it retains the look and feel of the original DOS version. Examples of the new DAS 1.5 graphical user interface can be seen in Appendix B. DAS 1.5 will run on Windows 95, 98, ME and NT versions of the operating system.

1.2 Background on Use of DAS

DAS Version 1.5 has three components, as presented in the entry level (MAIN) menu of the program (Figure 1-1):

1. An area for assessment of programs relative to the guidelines (the top selection in this menu);
2. Five sections on the evaluation of mitigation options for each of the five guideline areas from the Safety Standard (the next 5 selections in this menu);
3. A set of utility options to customize user input and to perform calculations related to orbital debris assessment issues.

In performing a debris assessment the user will first evaluate the program for compliance with the guidelines by exercising the areas under the first option. These areas are discussed in some detail in Section 3 of this manual. The input values and resulting output tables and data displays are sufficient to enter into the recommended debris assessment form as defined in Section 8 of the Safety Standard.

If a program fails to meet some of the guidelines, the analysis sections provide the user with further methods of exploring mitigation options. If general questions arise concerning the debris assessments, the user may elect to use the utility areas.

MAIN MENU

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Assessment of Guidelines
Analysis of Debris Released During Normal Operations (Guideline 3.X)
Analysis of Accidental Explosions / Intentional Breakups (Guideline 4.X)
Analysis of Debris Generated by On-Orbit Collisions (Guideline 5.X)
Analysis of Postmission Disposal of Space Structures (Guideline 6.X)
Analysis of Debris Reentry Risk after Postmission Disposal (Guideline 7.X)

Science / Engineering Utilities
Data and Screen Management Utilities
User Help

Quit Program

Figure 1-1. Entry Menu for the Debris Assessment Software

1.3 User Help

The DAS software does not come with a comprehensive set of user's manuals but rather provides on-line user help during program execution in several forms:

1. User Help section from the Main Menu
   This option produces help messages on various general topics related to the use of the DAS.
2. User Help invoked by entering <alt-H> or by selecting the Help menu item at the top of the window. This option produces a help message specifically directed to the current user screen. These messages are not complete for all screens.
3. Help on Use of the DAS Table Editor
   The DAS table editor is used to enter multi-column spreadsheet style data tables and to

present some types of tabular output. There is a complete set of help messages on the use of this editor that is accessed by entering <alt-H> or by selecting the Help menu item at the top of the window when in the table editor.

1.4 Terminology

Several terms used in this manual are defined here.

Table 1-1. Definition of Commonly Used Terms in the Operator's Manual

TERM	SYMBOL	DEFINITION
Low Earth Orbit	LEO	Near-Earth space to an altitude of 2000 km.
Geosynchronous Orbit	GEO	Any orbit with a period equal to the Earth's sidereal day. In DAS this is an orbit with an average altitude of 35788 km.
Semisynchronous Orbit	SSO	An orbit with a 12 hour period. In DAS this is an orbit with an average altitude of 20,233 km.
Geosynchronous Transfer Orbit	GTO	A highly eccentric orbit designed to transfer payloads from low altitude to GEO.
Solar Activity	F10	Solar flux measured at a wavelength of 10.7 cm; an indicator of the effect of the solar energy flux on the Earth's atmosphere. The larger F10 the more active the sun and the greater the atmospheric density at a given altitude. High solar activity reduces orbit lifetimes.
Solar Flux Unit	SFU	A measure of the solar flux at a wavelength of 10.7 cm. 1 sfu is 10^4 Janskys or 10^{-22} watts/m^2-sec.
Disposal Orbit		An orbit into which a payload or upper stage is transferred after mission completion. These orbits are of two types: storage orbits and reentry orbits
Storage Orbit		A destination orbit for postmission disposal in which the payload or upper stage will remain permanently, but one which greatly reduces the probability that there will be conflicts with active systems at a later time.
Reentry Orbit		A destination orbit for postmission disposal which is designed to have atmospheric drag remove the payload or upper stage from orbit in a timely manner.

2. OVERVIEW OF FEATURES AVAILABLE IN SOFTWARE

The Debris Assessment Software (DAS) provides the user with a set of screens to evaluate NASA space programs relative to the NASA debris mitigation guidelines and to assess options a program might pursue to satisfy the guidelines. The user interaction with DAS is discussed in more detail in Appendix B. The software is structured to parallel Safety Standard 1740.14: Guidelines and Assessment Procedures to Limit Orbital Debris Generation.

The software is organized into nine broad areas that are accessed from the entry level (or main) menu of the program. These areas are:

1. Assessment of Guidelines
2. Analysis of Debris Released During Normal Operations
3. Analysis of Accidental Explosions / Intentional Breakups
4. Analysis of Debris Generated by On-Orbit Collisions
5. Analysis of Postmission Disposal of Space Structures
6. Analysis of Debris Reentry Risk after Postmission Disposal
7. Science/Engineering Utilities
8. Data and Screen Management Utilities
9. User Help

The first option provides evaluation criteria for each guideline presented in the safety standard. The next five areas provide analyses that allow the user to assess options to bring a program into compliance for each guideline. General purpose utilities (e.g., calculating debris fluxes given a debris size) are provided in the Science/Engineering Utilities section. Utilities to manage the user-defined data files and to set software default values are provided in the Data and Screen Management Utilities section. General user help messages may be accessed via the User Help section.

The program is generally self-guiding. Analysis options used specifically to evaluate a program or project relative to a guideline are identified in the description of the options displayed on the screen. Other options are also contained in the software to assist the user in investigating mitigation measures to bring the program within guidelines.

If a program does not fall within a guideline, the DAS provides the user with mitigation options to bring the program into compliance. The types of mitigation analyses that are supported by the software include:

1. Analysis for Debris Released During Normal Operation (Chapter 4.1)

   This section calculates orbit lifetimes and related quantities given area-to-mass ratio, level of solar activity, and initial orbit. Calculations can include the effects of lunar and solar perturbations for highly eccentric orbits.

2. Analysis of Accidental Explosions / Intentional Breakups (Chapter 4.2)

There are no supporting analyses for this section.

3. Analysis of Debris Generated by On-Orbit Collisions (Chapter 4.3)

This section calculates:

- probability of collision with large objects based on mission orbit altitude, cross-sectional area, and mission duration
- collision probability with small debris for average spacecraft cross-sectional area, mission orbit, and mission duration
- flux to limiting size onto specific spacecraft surface elements
- debris penetration flux

In all cases, the environment may be the manmade environment, the meteoroid environment, or the combined environments.

4. Analysis of Postmission Disposal of Space Structures (Chapter 4.4)

For structures in or passing through LEO, this section assesses whether the 25 year guideline will be met for atmospheric reentry and calculates the postmission disposal maneuver performance requirement to reduce the orbit lifetime to 25 years if the guideline is not met. Lunar and solar perturbations may be used to reduce orbit lifetime for highly eccentric orbits.

For objects in GEO, this section includes an analysis of performance requirements to maneuver to storage orbits between LEO and GEO or above GEO.

The postmission disposal performance requirements may be stated in terms of:

- velocity change (Δv)
- propellant mass fraction given specific impulse of the postmission disposal motor
- propellant mass given total mass of the vehicle at the end of mission life and specific impulse of the postmission disposal motor
- specific impulse required for the postmission disposal motor given available propellant mass fraction at the end of mission

5. Analysis of Debris Reentry Risk after Postmission Disposal (Chapter 4.5)

For uncontrolled reentry, i.e., reentry where there is no control of the location of the reentry ground footprint, this section calculates the number and size of debris surviving reentry and the estimated debris casualty area.

For controlled reentry, where the reentry ground footprint location is controlled by the program or project, this section calculates the performance requirements for immediate reentry and the estimated ground impact footprint location.

The utilities contained in the DAS include:

1. Science/Engineering Utilities (Chapter 5.1)

   This section calculates:

   a. the impactor diameter given a probability of impact for orbital debris, meteoroids, or the combined environments;
   b. the probability of impact given impactor diameter for orbital debris, meteoroids, or the combined environments;
   c. the initial reentry orbit and the maneuver requirement to transfer to that orbit from a final mission orbit, area-to-mass ratio, desired decay orbit lifetime, and level of solar activity;
   d. the Δv required for transfer between orbits;
   e. the various relationships between Δv, propellant mass fraction, propellant mass, initial mass, and specific impulse;
   f. the decay orbit or Δv given an initial orbit and an orbit lifetime;
   g. the debris orbit and lifetime given a Δv;
   h. the orbit lifetime with time varying solar activity;
   i. the apogee/perigee altitude history for a specified orbit.

2. Data and Screen Management Utilities (Chapter 5.2)

   These utilities allow the user to:

   a. modify materials data base (used in estimating penetration probability, reentry survivability).
   b. save user default values (makes the software default values those specified by the user).
   c. maintain user data files (this option lists the user output data files, plot files, and activity logs stored on the user's disk - later versions of the software will allow the users to delete these files from within the program).

3. User Help (Chapter 5.3)

   These user help messages provide general information on the software, as opposed to the on-line user help messages that are specific for the menu shown on the screen when the on-line help is requested.

3. EVALUATING PROGRAMS RELATIVE TO THE DEBRIS GUIDELINES

This section of the software determines whether a program satisfies the guideline conditions. If the program passes all guideline tests, no additional evaluation is required. If the program fails, alternatives may be assessed by choosing the analysis options, which are grouped by guideline area. The discussion in this area will extend to all user input and output screens, including a discussion of data input requirements for each guideline assessment.

The evaluation of guidelines option is invoked by choosing the top selection from the Main Menu, the option titled "Assessment of Guidelines". There are two types of guidelines encountered in performing these evaluations. There are guidelines where some analysis is required to determine if the guideline is satisfied by the program. This type of guideline is for debris released during normal operations, for example, where the orbit lifetime for the debris needs to be calculated before it can be determined whether the program will satisfy the guidelines. The second type of guideline does not require analysis. The guideline to transfer to a storage orbit after completion of a mission is an example of this type of guideline. For this type of guideline the software provides the user with performance requirements to transfer to this orbit, and the program can then determine whether such a set of maneuvers can be performed.

The program structure will be discussed in terms of the five guideline areas. The software evaluates the specific conditions for a particular program relative to the guidelines. The menu options for this area are in Table 3-1. The DAS processing following selection of one of these five options is presented in Sections 3.1 through 3.5.

Table 3-1. Outline of Menu Options for Evaluation Relative to Debris Guidelines

Evaluation for Guideline Area 3 (Debris Released During Normal Operations)
Evaluation for Guideline Area 4 (Accidental Explosions and Intentional Breakups)
Evaluation for Guideline Area 5 (Debris Generated by On-Orbit Collisions)
Evaluation for Guideline Area 6 (Postmission Disposal of Space Structures)
Evaluation for Guideline Area 7 (Debris Reentry Risk After Postmission Disposal)

3.1 Evaluation for Guideline Area 3 (Debris Released During Normal Operations)

This section calculates changes in the orbit of debris released during normal operations. The guidelines constrain the orbit lifetime for such debris in or passing through LEO and the time that such debris may remain in an orbit that potentially conflicts with GEO satellites. Debris released during normal operations includes staging components such as clamp bands and debris released during payload deployment, such as lens covers. It does not include rocket bodies or payloads left in orbit; these are addressed in guideline area 6 on postmission disposal. For debris that remains in low Earth orbit, lifetime will be controlled by atmospheric drag. However, for debris in highly eccentric orbit, with apogee altitudes above roughly 10,000 km, lunar and solar gravitational perturbations can also affect orbit lifetime.

The outline for the menu options for this section are presented in Table 3.1-1.

Table 3.1-1. Outline of Menu Options for Assessment of Debris Released During Normal Operations

Evaluate for Guideline 3-1 (Area-Time and Object-Time Products)
Evaluate for Guideline 3-2 (Lowering Apogee Below GEO Within 25 Years)

3.1.1 User Input for Guideline 3-1

The user input screen is entered when **Evaluate for Guideline 3-1 (Area-Time and Object-Time Products)** is selected and the user elects to input data. For Guideline 3-1 the user inputs are:

Reference Orbit Apogee Altitude
Reference Orbit Perigee Altitude
Debris Data

The reference orbit is the orbit of the system at the time of debris release. The debris data consists of the following:

Name of debris object
Number of such objects
Average cross-sectional area
Area-to-mass ratio
Difference in apogee / perigee altitude from reference orbit

This information on the debris object is sufficient to determine its orbit lifetime and, using the area, its area-time product. Objects may be collected into a group to make the number of objects larger than 1 if they have the same area-to-mass, average cross-sectional area, and initial orbit. The debris data is entered in a data table that may be saved by the user; the default table name is DEMO3. The data is entered and changed using a table editor contained within DAS. The option to save the data can be exercised when the user exits the table editor. If the user elects to save the file, the user enters a new file name at the file name prompt and adds a descriptive phrase for the table label.

The data input screen with default values is shown in Figure 3.1-1. The debris data are entered in a table using the table editor. The form of the debris data input can be seen by looking through DEMO3.

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Initial Orbit Data:
Reference Apogee Altitude........ 600.000000 km
Reference Perigee Altitude........ 600.000000 km
Other Data:
Operational Debris File Name.... DEMO3

Message on Data Input Limits for Highlighted Line

Figure 3.1-1. User Input Screen for Evaluating Guideline 3-1.

3.1.2 DAS Output for Guideline 3-1

The DAS output for the guideline evaluation is in the form of a data table. The output for the default data is shown in Figure 3.1-2. The table provides some of the user input data, but also includes results of the orbit lifetime calculations: dwell time below 2000 km altitude, and the object-time and area-time products for each type of debris.

For the particular case shown, the program fails the guidelines because the area-time product of the lens cap is larger than the limit of 0.1 m^2-yr. The user would therefore assess alternatives to reduce the orbit lifetime or reduce the average cross-sectional area of the cap or both using the analysis section of the DAS for this guideline area. Alternatives might include dropping the cover in an orbit of slightly lower perigee altitude, reducing the weight of the lens cap to increase the area-to-mass ratio and decrease the orbit lifetime, or retaining the lens cap with the payload.

OUTPUT TABLE FROM CALCULATION ON AREA-TIME/OBJECT-TIME PRODUCTS

Reference Orbit Apogee Altitude.... 600.00000000 km
Reference Orbit Perigee Altitude.... 600.00000000 km

FAILS GUIDELINE - AREA-TIME EXCEEDS GUIDELINES

Debris Name	Number of Objects	Total Area (m^2)	Total Mass (kg)	Area-to-Mass (m^2/kg)	Apogee Alt. (km)	Perigee Alt. (km)	Dwell Time (yr)	Object-Time (yr)	Area-Time (m^2-yr)
Lens Caps	1	0.0353	0.7	0.050429	600	600	2.977629	2.977629	0.10511
Pins	5	0.001765	0.04215	0.041874	600	600	3.585917	17.92958	0.006329
Totals:	6	0.037065	0.74215					20.90721	0.111439

Figure 3.1-2. Output Table for Guideline 3-1

3.1.3 User Input for Guideline 3-2

The user input for this guideline is the same as that for Guideline 3-1. The user input screen is entered once **Evaluate for Guideline 3-2 (Lowering Apogee Below GEO Within 25 Years)** is selected and the user elects to input data. For Guideline 3-2 the user inputs are:

Reference Orbit Apogee Altitude
Reference Orbit Perigee Altitude
Debris Data

The reference orbit is the orbit of the system at the time of debris release. The debris data consists of the following:

Name of debris object
Number of such objects
Average cross-sectional area
Area-to-mass ratio
Difference in apogee / perigee altitude from reference orbit

This information on the debris object is sufficient to determine the reduction in orbit apogee altitude caused by atmospheric drag, a simplification in orbit evolution calculations allowed by the Standard - that solar activity may be assumed constant at an F10 of 130 SFU and lunar/solar perturbations may be neglected. Objects may be collected into a group to make the number of objects larger than 1 if they have the same area-to-mass ratio and initial orbit.

The data input screen with default values is shown in Figure 3.1-3. The debris data are entered in a table using the table editor. The form of the debris data input can be seen by looking through DEMO3.

```
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Initial Orbit Data:
        Reference Apogee Altitude........  35788.000000 km
        Reference Perigee Altitude........   200.000000 km
Other Data:
        Operational Debris File Name....  DEMO3

          Message on Data Input Limits for Highlighted Line
```

Figure 3.1-3. User Input Screen for Evaluating Guideline 3-2.

3.1.4 DAS Output for Guideline 3-2

The DAS output for the guideline evaluation is in the form of a data table. The output for the default data is shown in Figure 3.1-4. The table provides some of the user input data, but also includes results of the orbit evolution calculations in the form of the maximum perigee altitude the debris object could have to satisfy the guidelines. If the reference orbit perigee altitude is above this value, the debris will experience too little atmospheric drag to lower its apogee sufficiently far below GEO in the alloted time. For the default case, the maximum perigee altitude is above that of the reference orbit for both types of operational debris, so the program passes this guideline.

If the test against the guidelines failed the user would assess alternatives to demonstrate greater apogee lowering. Options that might be exercised include planning to reduce the reference orbit perigee altitude or increase the area-to-mass ratio of the offending debris objects, to calculate apogee lowering using a more realistic prediction of time-dependent solar activity, or finally to calulate the orbit evolution considering lunar/solar perturbations. Alternatives might include reducing the weight of the debris to increase the area-to-mass ratio or adjusting planned launch date or time to use lunar/solar perturbations to lower the average perigee altitude to increase the effects of atmospheric drag. These options can all be considered within DAS.

OUTPUT TABLE FROM CALCULATION TO LOWER APOGEE 300 KM BELOW GEO

Reference Orbit Apogee Altitude.... 37588.00000000 km
Reference Orbit Perigee Altitude. .. 200.00000000 km

PASSES GUIDELINE

Debris Name	Number of Objects	Total Area (m^2)	Total Mass (kg)	Area-to-Mass (m^2/kg)	Apogee Alt. (km)	Perigee Alt. (km)	Max. Perigee Alt. (km)	Pass/Fail Guidelines
Lens Caps	1	0.0353	0.7	0.050429	37588	200	457.86	PASS
Pins	5	0.001765	0.04215	0.041874	37588	200	446.83	PASS
Totals:	6	0.037065	0.74215					

Figure 3.1-4. Output Table for Guideline 3-2

3.2 Evaluation for Guideline Area 4 (Accidental Explosions and Intentional Breakups)

There is no analysis software for this guideline area, so the options in this area only provide the user with informative messages concerning the guidelines. Special software is required for these guideline areas which is not a part of the DAS. The options are outlined in Table 3.2-1.

Table 3.2-1. Outline of Menu Options for Assessment of Accidental Explosions and Intentional Breakups

Evaluate for Guideline 4-1 (Accidental Explosions During the Mission)
Evaluate for Guideline 4-2 (Accidental Explosions After Mission Completion)
Evaluate for Guideline 4-3 (Intentional Breakups: Long-Term Risk from Planned Tests)
Evaluate for Guideline 4-4 (Intentional Breakups: Short-Term Risk from Planned Tests)
Evaluate for Guideline 4-5 (Intentional Breakups: As a Planned Reentry Procedure)

The messages associated with each of the guidelines in this area are presented in Figures 3.2-1 through 3.2-5.

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For preventing accidental explosions during mission : For quantification, 10^-4 has been given as a reference, but there is no general software available to assist the user in estimating the probability of accidental explosions.

Press any key to continue

Figure 3.2-1. DAS Message for Guideline 4-1.

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For preventing accidental explosions after mission completion : After completion of a mission, all sources of stored energy will be removed from the space system and design measures will be implemented to prevent the buildup of stored energy after completion of the mission. Depletion of stored energy includes venting or burning fuels, oxidizers, and other pressurized volumes, discharging batteries and breaking the charging circuits, and deactivating range safety systems.

Press any key to continue

Figure 3.2-2. DAS Message for Guideline 4-2.

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Evaluation of Intentional Breakups requires specialized software and breakup models. For assistance in such an evaluation, please contact the Orbital Debris Program Office at Johnson Space Center/SN3.

Press any key to continue

Figure 3.2-3. DAS Message for Guideline 4-3.

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Evaluation of Intentional Breakups requires specialized software and breakup models. For assistance in such an evaluation, please contact the Orbital Debris Program Office at Johnson Space Center/SN3.

Press any key to continue

Figure 3.2-4. DAS Message for Guideline 4-4.

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If a space system is intentionally destroyed to reduce survivability of components during atmospheric reentry, destruction should occur at an altitude below 90 kilometers. This ensures that there will be no debris left in long-life orbits, but allows destruction at an altitude where there is still control of the system.

Press any key to continue

Figure 3.2-5. DAS Message for Guideline 4-5.

3.3 Evaluation for Guideline Area 5 (Debris Generated by On-Orbit Collisions)

The objective of this guideline area is to make the user aware of the potential for creating debris as a result of on-orbit collisions. This debris might be created by a collision with another relatively large object in orbit or by a spacecraft being damaged so it cannot complete its mission and be removed from orbit.

The options in this area provide the user with informative messages concerning the guidelines along with a calculation of probability of collision with debris or meteoroids. See Section 4.3 of this manual for more assistance with quantitative assessments. The options are presented in Table 3.3-1.

Table 3.3-1. Menu Options for Assessment of Debris Generated by On-Orbit Collisions

Evaluate for Guideline 5-1 (Collisions with Large Debris)
Evaluate for Guideline 5-2 (Collisions with Small Debris)

The input data screen for calculating probability of impact with large debris is presented in Figure 3.3-1. The output screen for this option is presented in Figure 3.3-2.

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Apogee Altitude.................... 500.000000 km
Perigee Altitude.................... 500.000000 km
Avg. S/C X-Sectional Area... 10.000000 m^2
Mission Duration.................. 1.000000 yr.

Press any key to continue

Figure 3.3-1. DAS Input Screen for Guideline 5-1.

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The intent of the guideline is satisfied if the probability of collisions with large objects in orbit is no larger than 0.001. The analysis section of this software provides support in calculating probability of collision and probability of near-misses with orbital debris larger than 10 cm.

Apogee Altitude.................... 500.000000 km
Perigee Altitude.................... 500.000000 km
Avg. S/C X-Sectional Area... 10.000000 m^2
Mission Duration.................. 1.000000 yr.

Man-Made Debris Diameter (cm)	Meteoroid Diameter (cm)	Prob. of Impact with Man-Made	Prob. of Impact with Meteoroid	Total Prob. Of Impact
1.000E+01	1.000E+01	0.00001	2.138E-09	0.00001

Press any key to continue

Figure 3.3-2. DAS Output Screen for Calculating Probability of Collision with Large Debris (Guideline 5-1)

The input data screen for calculating probability of impact with small debris is presented in Figure 3.3-3. The output screen for this option is presented in Figure 3.3-4.

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Apogee Altitude.................. 500.000000 km
Perigee Altitude.................. 500.000000 km
Orbit Inclination................... 28.500000 deg
Avg. S/C X-Sectional Area... 10.000000 m^2
Mission Duration................. 1.000000 yr.
Launch Date....................... 1995.000000
Solar Activity....................... 130.000000 sfu
Debris Diameter.................. 0.500000 cm

Press any key to continue

Figure 3.3-3. DAS Input Screen for Guideline 5-2.

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The intent of the guideline is satisfied if the probability of collisions with orbital debris or meteoroids that would prevent postmission disposal is no larger than 0.01. The analysis section of this software provides support in calculating probability of collision and probability of damage resulting from collision.

Apogee Altitude.................... 500.000000 km
Perigee Altitude.................... 500.000000 km
Orbit Inclination................... 28.500000 deg
Avg. S/C X-Sectional Area... 10.000000 m^2
Mission Duration................. 1.000000 yr.
Launch Date....................... 1995.000000
Solar Activity....................... 130.000000 sfu

Man-Made Debris Diameter (cm)	Meteoroid Diameter (cm)	Prob. of Impact with Man-Made	Prob. of Impact with Meteoroid	Total Prob. of Impact
5.00E-01	5.00E-01	0.00061	0.00034	0.00095

Press any key to continue

Figure 3.3-4. DAS Output Screen for Calculating Probability of Collision with Small Debris (Guideline 5-2)

3.4 Evaluation for Guideline Area 6 (Postmission Disposal of Space Structures)

This section of the software supports the user in evaluating requirements for postmission disposal. The support in this area is therefore somewhat different than for the guidelines on operational debris. The user will need to determine whether the program will be able to satisfy these requirements. In the debris assessment report the program is asked to state the postmission disposal option and its plan for performing the postmission disposal operations.

The outline for the menu structure for this section of the software is presented in Table 3.4-1.

Table 3.4-1. Outline of Menu Options for Postmission Disposal of Space Structures

Evaluation for Guideline 6-1 (Orbits Passing Through LEO)
Evaluation for Guideline 6-2 (Orbits Above LEO)
Evaluation for Guideline 6-3 (Near-Circular 12-Hour Orbits)
Evaluation for Guideline 6-4 (Reliability of Postmission Disposal Options)

Programs with mission orbits in or passing through low Earth orbit will use the first option. Programs with spacecraft in the GEO region will use the second option; if an upper stage is left in a geosynchronous transfer orbit the postmission disposal options for that upper stages will be assessed using the first option. Programs sending payloads to a circular semi-synchronous orbit will use the third option, but if an upper stage is left in elliptical transfer orbit for a circular semi-synchronous mission orbit the postmission disposal options for that upper stage will be assessed using the first option.

3.4.1 Evaluation for Guideline 6-1

Guideline 6-1 applies to payloads or upper stages left in LEO orbit or in orbits passing through LEO, such as GTO or other highly eccentric orbits. The options which can be evaluated are disposal by atmospheric reentry and transfer to a storage orbit.

Table 3.4-2. Outline of Menu Options for Postmission Disposal of Space Structures
Evaluation for Guideline Area 6-1 (Orbits Passing Through LEO)

Evaluate for Guideline 6-1a (Disposal by Atmospheric Reentry)
Evaluate for Guideline 6-1b (Transfer to Storage Orbit)
Evaluate for Guideline 6-1c (Direct Retrieval)

The first two options lead to user input and DAS output; the third option yields only a message.

3.4.1.1 User Input for Guideline 6-1a

The user input for this guideline is similar to that for guideline 3-1. The user input screen is entered once **Evaluate for Guideline 6-1a (Disposal by Atmospheric Reentry)** is selected and the user elects to input data. For Guideline 6-1a the user inputs are:

Apogee Altitude
Perigee Altitude
Area-to-Mass Ratio

The orbit apogee and perigee altitude is for the orbit of the payload or upper stage after completion of mission and all postmission disposal maneuvers. The area-to-mass ratio is for the payload or upper stage after completion of the postmission disposal maneuver.

This information on the object is sufficient to determine its orbit lifetime, which according to the guidelines should be no more than 25 years.

The data input screen with default values is shown in Figure 3.4-1.

NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.0

Initial Orbit Data :
Apogee Altitude....................... 600.000000 km
Perigee Altitude....................... 600.000000 km

Other Data :
Area to Mass.......................... 0.010000 m^2/kg

Message on Data Input Limits for Highlighted Line

Figure 3.4-1. User Input Screen for Evaluating Guideline 6-1a.

3.4.1.2 DAS Output for Guideline 6-1a

The DAS output for this guideline evaluation is presented in an output screen. The output for the default data is shown in Figure 3.4-2. The table provides some of the user input data, but also includes results of the orbit evolution calculations in the form of the orbit lifetime. As can be seen in the figure, the default values lead to an orbit lifetime less than 25 years, and so the program would pass this guideline.

If the evaluation had failed, the user would begin to assess alternatives to reduce the orbit lifetime using the analysis section of the DAS for this guideline area. Alternatives might include postmission disposal to a lower perigee altitude orbit or checking to see if the time of mission completion would be at such a time in the solar cycle as to decrease the orbit lifetime.

NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.0

Initial Orbit Data :
Apogee Altitude....................... 600.000000 km
Perigee Altitude....................... 600.000000 km

Other Data :
Area to Mass.......................... 0.010000 m^2/kg
Calculated Orbit Lifetime........ 15.015770 yr

PASSES GUIDELINE

Press any key to continue

Figure 3.4-2. Output Screen for Evaluating Guideline 6-1a.

3.4.1.3 User Input for Guideline 6-1b

The user input for this guideline is similar to that for guideline 3-1. The user input screen is entered once **Evaluate for Guideline 6-1b (Transfer to Storage Orbit)** is selected and the user elects to input data. For Guideline 6-1a the user inputs are:

Apogee Altitude
Perigee Altitude
Specific Impulse

The reference orbit is the orbit of the system after completion of mission and all postmission disposal maneuvers. The specific impulse refers to the propulsion system performing the postmission disposal maneuver. This information is sufficient to determine the propellant mass fraction required to transfer to a minimum altitude disposal orbit.

The data input screen with default values is shown in Figure 3.4-3.

NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.5

Apogee Altitude....................... 600.000000 km
Perigee Altitude....................... 600.000000 km
Specific Impulse...................... 250.000000 sec

Message on Data Input Limits for Highlighted Line

Figure 3.4-3. User Input Screen for Guideline 6-1b.

3.4.1.4 DAS Output for Guideline 6-1b

The DAS output for the guideline evaluation is presented in an output screen. The output for the default data is shown in Figure 3.4-4. The output provides some of the user input data, but also includes results of the orbit evolution calculations in the form of the orbit lifetime. As can be seen in the figure, the default values lead to an orbit lifetime of less than 25 years, and so the program would pass this guideline.

If the evaluation indicates greater resource requirements than the program has available, the user would begin to assess alternatives in the DAS for this guideline area. Alternatives might include using a postmission disposal maneuvering system with higher specific impulse or increasing the propellant available at the time the maneuver is performed.

NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.5

Apogee Altitude....................... 1500.000000 km
Perigee Altitude....................... 1500.000000 km
Specific Impulse........................ 250.000000 sec

Delta-V...................................... 280.773700 m/s
Propellant Mass Fraction..................0.108284
Storage Orbit Apogee Altitude.. 2500.000000 km
Storage Orbit Perigee Altitude.. 2500.000000 km

Press any key to continue

Figure 3.4-4. Output Screen for Guideline 6-1b.

3.4.1.5 DAS Message for Guideline 6-1c

This option is encountered when the user elects **Evaluate for Guideline 6-1c (Direct Retrieval)** as shown in figure 3.4-5. There is no analysis software for this guideline area, so the options in this area only provide the user with informative messages concerning the guidelines.

NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.5

This assessment is based on a qualitative guideline. For quantification, 0.99 has been given as a reference. For assistance in estimating the probability in performing a successful postmission disposal manuever, contact the Orbital Debris Program Office at NASA Johnson Space Center/SN3.

Press any key to continue

Figure 3.4-5. DAS Message for Guideline 6-1c.

3.4.2 Evaluation for Guideline 6-2

For programs that have payloads or upper stages that do not pass through LEO, the options exercised for postmission disposal will most often be to leave the payload or spacecraft in place or transfer to a storage orbit. For GEO programs that fall within guideline 6-2 the options are as shown in Table 3.4-3.

Table 3.4-3 Outline of Menu Options for Postmission Disposal of Space Structures
Evaluation for Guideline 6-2 (Orbits Above LEO)

Evaluate for Guideline 6-2a (Transfer to Super-GEO Storage Orbit)
Evaluate for Guideline 6-2b (Transfer to Storage Orbit Between LEO & GEO)

3.4.2.1 User Input for Guideline 6-2a

The user input for this guideline is similar to that for guideline 3-1. The user input screen is entered once **Evaluate for Guideline 6-2a (Transfer to Super-GEO Storage Orbit)** is selected and the user elects to input data. For Guideline 6-2a the user inputs are:

Apogee Altitude
Perigee Altitude
Specific Impulse

The reference orbit is the operational orbit of the system. The specific impulse refers to the propulsion system performing the postmission disposal maneuver.

This information on the object is sufficient to determine the magnitude of the maneuver required to reach an acceptable disposal orbit and the propellant mass fraction these maneuvers would require.

The data input screen with default values is shown in Figure 3.4-6.

NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.5

Oper. Alt. Relative to GEO:

Initial Orbit Apogee.................	0.000000 km
Initial Orbit Perigee.................	0.000000 km
Specific Impulse......................	250.000000 sec

Message on Data Input Limits for Highlighted Line

Figure 3.4-6. User Input Screen for Evaluating Guideline 6-2a.

3.4.2.2 DAS Output for Guideline 6-2a

The DAS output for the guideline evaluation is presented in an output screen. The output for the default data is shown in Figure 3.4-7. The table provides some of the user input data, but also includes results of the orbit transfer calculations.

```
NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.5

Altitudes Relative to GEO:
        Initial Orbit Apogee Altitude.....      0.000000  km
        Initial Orbit Perigee Altitude.....     0.000000  km
        Specific Impulse.....................  250.000000  sec

        Delta-V..................................  10.880700  m/s
        Propellant Mass Fraction..............0.004431
        Storage Orbit Apogee Altitude.  300.000000  km
        Storage Orbit Perigee Altitude.  300.000000  km

Press any key to continue
```

Figure 3.4-7. Output Screen for Evaluating Guideline 6-2a.

3.4.2.3 User Input for Guideline 6-2b

The user input for this guideline is the same as that for guideline 6-2a. The user input screen is entered once **Evaluate for Guideline 6-2b (Transfer to Storage Orbit Between LEO & GEO)** is selected and the user elects to input data. For Guideline 6-2a the user inputs are:

Apogee Altitude
Perigee Altitude
Specific Impulse

The reference orbit is the operation orbit of the system. The specific impulse refers to the propulsion system performing the postmission disposal maneuver.

This information on the object is sufficient to determine the magnitude of the maneuver required to reach an acceptable disposal orbit and the propellant mass fraction these maneuvers would require.

The data input screen with default values is shown in Figure 3.4-8.

NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.5

Operational Orbit Apogee.................. 35788.000000 km
Operational Orbit Perigee.................. 2000.000000 km
Specific Impulse...................... 250.000000 sec

Message on Data Input Limits for Highlighted Line

Figure 3.4-8. User Input Screen for Evaluating Guideline 6-2b.

3.4.2.4 DAS Output for Guideline 6-2b

The DAS output for the guideline evaluation is presented in an output screen. The output for the default data is shown in Figure 3.4-9. The table provides some of the user input data, but also includes results of the orbit transfer calculations.

If the evaluation had failed the user would begin to assess alternatives to reduce the orbit maneuver requirement using the assessment section of the DAS for this guideline area. Alternatives might include changing the postmission disposal propulsion systems to one having a higher specific impulse or adding enough propellant to the propulsion systems to accomodate the larger burn requirement.

NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.5

Altitudes Relative to GEO:

Operational Apogee Altitude.....	35788.000000	km
Operational Perigee Altitude.....	2000.000000	km
Specific Impulse.....................	250.000000	sec
Delta-V..................................	52.092900	m/s
Propellant Mass Fraction..................	0.021039	
Storage Orbit Apogee Altitude.	35287.000000	km
Storage Orbit Perigee Altitude.	2500.000000	km

Press any key to continue

Figure 3.4-9. Output Screen for Evaluating Guideline 6-2b.

3.4.3 Evaluation for Guideline 6-3

For programs with objects in circular SSO, the disposal options are to transfer to storage orbits away from SSO. These options are stated in Table 3.4-4.

Table 3.4-4. Outline of Menu Options for Postmission Disposal of Space Structures
Evaluation for Guideline Area 6-3 (Near Circular 12-Hour Orbits)

Evaluate for Guideline 6-3a (Transfer to Storage Orbit Above SSO)
Evaluate for Guideline 6-3b (Transfer to Storage Orbit Below SSO)

Once the user selects any storage orbit option, the software allows the user to evaluate for the guideline. The user selects the first option to assess the performance requirement for transfer to a storage orbit above SSO and the second option to perform parametric studies for requirements for transfer to a storage orbit below SSO.

3.4.3.1 User Input for Guideline 6-3a

The user input for this guideline is the same as for guideline 6-2a or b. The user input screen is entered once **Evaluate for Guideline 6-3a (Transfer to Storage Orbit Above SSO)** is selected and the user elects to input data. For Guideline 6-3a the user inputs are:

Apogee Altitude
Perigee Altitude
Specific Impulse

The orbit apogee/perigee altitude is for the operational orbit of the payload or upper stage. The specific impulse refers to the propulsion system performing the postmission disposal maneuver.

This information on the object is sufficient to determine the magnitude of the maneuver required to reach an acceptable disposal orbit and the propellant mass fraction these maneuvers would require.

The data input screen with default values is shown in Figure 3.4-10.

NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.5

Oper. Alt. Relative to SSO:

Initial Orbit Apogee..................	0.000000 km
Initial Orbit Perigee..................	0.000000 km
Specific Impulse......................	250.000000 sec

Message on Data Input Limits for Highlighted Line

Figure 3.4-10. User Input Screen for Evaluating Guideline 6-3a.

3.4.3.2 DAS Output for Guideline 6-3a

The DAS output for the guideline evaluation is presented in an output screen. The output for the default data is shown in Figure 3.4-11. The table provides some of the user input data, but also includes results of the orbit transfer calculations.

If the evaluation had failed the user would begin to assess alternatives to reduce the orbit maneuver requirement using the analysis section of the DAS for this guideline area. Alternatives might include changing the postmission disposal propulsion systems to one having a higher specific impulse or adding enough propellant to the propulsion systems to accomodate the larger burn requirement.

NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.5

Altitudes Relative to SSO:

Initial Orbit Apogee Altitude.....	0.000000	km
Initial Orbit Perigee Altitude.....	0.000000	km
Specific Impulse......................	250.000000	sec
Delta-V...................................	21.633700	m/s
Propellant Mass Fraction...............	0.008792	
Storage Orbit Apogee Altitude.	300.000000	km
Storage Orbit Perigee Altitude.	300.000000	km

Press any key to continue

Figure 3.4-11. Output Screen for Evaluating Guideline 6-3a.

3.4.3.3 User Input for Guideline 6-3b

The user input for this guideline is the same as that for guideline 6-3a. The user input screen is entered once **Evaluate for Guideline 6-3b (Transfer to Storage Orbit Below SSO)** is selected and the user elects to input data. For Guideline 6-3b the user inputs are:

Apogee Altitude
Perigee Altitude
Specific Impulse

The reference orbit is the operational orbit of the system. The specific impulse refers to the propulsion system performing the postmission disposal maneuver.

This information on the object is sufficient to determine the magnitude of the maneuver required to reach an acceptable disposal orbit and the propellant mass fraction these maneuvers would require.

The data input screen with default values is shown in Figure 3.4-12.

NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.5

Oper. Alt. Relative to SSO:

Initial Orbit Apogee..................	0.000000 km
Initial Orbit Perigee..................	0.000000 km
Specific Impulse......................	250.000000 sec

Message on Data Input Limits for Highlighted Line

Figure 3.4-12. User Input Screen for Evaluating Guideline 6-3b.

3.4.3.4 DAS Output for Guideline 6-3b

The DAS output for the guideline evaluation is presented in an output screen. The output for the default data is shown in Figure 3.4-13. The table provides some of the user input data, but also includes results of the orbit transfer calculations.

If the evaluation had failed the user would begin to assess alternatives to reduce the orbit maneuver requirement using the assessment section of the DAS for this guideline area. Alternatives might include changing the postmission disposal propulsion systems to one having a higher specific impulse or adding enough propellant to the propulsion systems to accomodate the larger burn requirement.

NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.5

Altitudes Relative to SSO:

```
Initial Orbit Apogee Altitude.....      0.000000   km
Initial Orbit Perigee Altitude.....     0.000000   km
Specific Impulse...................   250.000000   sec

Delta-V............................    22.002650   m/s
Propellant Mass Fraction...............0.008941
Storage Orbit Apogee Altitude. -300.000000   km
Storage Orbit Perigee Altitude. -300.000000   km
```

Press any key to continue

Figure 3.4-13. Output Screen for Evaluating Guideline 6-3b.

3.4.3.5 Guideline 6-4

There is no analysis software for this guideline area on reliability of the postmission disposal option, so this area only provides the user with informative messages concerning the guidelines, as shown in Figure 3.4-14.

NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.5

There is currently no DAS analysis to support this guideline.
The objective of the guideline is to ensure that space systems will be able to perform the post-mission disposal maneuver with a high level of reliability. As a quantitative reference, when the probability of sucessfully performing the post-mission disposal maneuver exceeds 0.99, the intent of the guideline has been met. If there is not a requirement for performing a maneuver at the end of the mission (for example, if the lifetime in the final mission orbit is less than 25 years), this guideline does not apply.

Press any key to continue

Figure 3.4-14. DAS Message for Guideline 6-4.

3.5 Evaluation for Guideline 7 (Debris Reentry Risk After Postmission Disposal)

The objective of this section is to provide the user with a model for survivability of reentering spacecraft hardware to determine if a significant amount of material will survive reentry. In the assessment of alternatives the software has options to study requirements for controlled reentry and to perform preliminary assessments on the location of the reentry footprint relative to the reentry maneuver required to control the ground impact point.

The outline for the assessment options in this section are provided in Table 3.5-1.

Table 3.5-1. Outline of Menu Options for Assessment of Debris Reentry Risk after Postmission Disposal

Evaluate for Guideline 7-1 (Uncontrolled Reentry from Decaying Orbits)

If Guideline 7-1 is violated by a program there is no specific area in the software per se to study techniques to reduce survivability. This can be done to a limited extent within the evaluation section by changing the materials used to materials less likely to survive reentry heating (i.e. using materials with lower melting temperatures or lower specific heat), designing the system to remain essentially intact, or intentionally breaking up the reentering structure.

3.5.1 User Input for Guideline 7-1

The user input screen is entered when **Evaluate for Guideline 7-1 (Uncontrolled Reentry from Decaying Orbits)** is selected and the user elects to input data. For Guideline 7-1 the user inputs are the altitude at which the primary system structure fails as a result of reentry heating and aerodynamic forces and a file of component and materials data to evaluate survivability for components released into the atmosphere at the specified breakup altitude. No other orbit information is required because it is assumed that uncontrolled reentry is coming from the decay of a low eccentricity orbit. The 78 km default altitude for breakup was chosen from studies of a number of reentering systems. If the user has reason to believe breakup will occur at another altitude, this altitude should be used in the assessment.

The component and materials data are contained in an input table and consists of the following:

Name of component
Number of such objects
Component shape
Average cross-sectional area
Mass
Material comprising the component

This information on the debris object is sufficient to determine its survivability for unprotected passage through the atmosphere given the breakup altitude. Components may be collected into a group to make the number of objects larger than 1 if they have the same mass, average cross-sectional area, and materials composition. The data is entered in a data table that may be saved by the user; the default table name is DEMO7. The data is entered and changed using a table editor contained within DAS. The option to save the data can be exercised when the user exits the table editor. If the user elects to save the file, enter a new file name at the file name prompt and add a descriptive phrase for the table label.

The data input screen with default values is shown in Figure 3.5-1. The debris data are entered in a table using the table editor. The form of the debris data input can be seen in looking through DEMO7.

NASA DEBRIS ASSESSMENT SOFTWARE
VERSION 1.5

Breakup Altitude........................ 78.000000 km
Object Data File........................ DEMO7

Message on Data Input Limits for Highlighted Line

Figure 3.5-1. User Input Screen for Evaluating Guideline 7-1.

3.5.2 DAS Output for Guideline 7-1

The DAS output for the guideline evaluation is in the form of a data table. The output for the default data is shown in Figure 3.5-2. The table provides some of the user input data, but also includes results of the survivability calculations. Objects that survive reentry have a demise altitude of 0 km and an associated debris casualty area. The debris casualty area is essentially the collision cross-section for impact with a human and is the average cross-sectional area of the object plus an additional boundary area to account for the finite size of a human. This quantity is defined more precisely in the Standard. It can be seen from this output that the program passes this guideline test because the total debris casualty area is 6.4771 m^2, which is less than the maximum allowed 8 m^2.

If the program had failed this guideline, the user would begin to assess alternatives to reduce survivability of the components or to plan for targeted reentry rather than uncontrolled reentry. Alternatives might include using materials that are less survivable or causing breakup to occur at a higher altitude.

UNCONTROLLED REENTRY FROM DECAYING ORBITS
*** Parent Object Data is in line 1 ***
Total Debris Casualty Area.... 6.47719500 m^2

Object Surface Identification	Object Type	Object Diameter (m)	Object Length (m)	Object Height (m)	Object Mass (kg)	Material Type	Demise Altitude (km)	Casualty Area (m^2)
Parent	Cylinder	0.762	3.3	0	1289	SS 21-6-9	78	0
exp mod 1	Cylinder	0.279	2.64	0	40.8	Al 2024-T8xx	69.6517	0
exp mod 2	Cylinder	0.305	2.59	0	50	Al 2024-T8xx	68.4411	0
grapple 1	Sphere	0.295	0	0	37.6	Titanium	0	0.6291
grapple 2	Sphere	0.413	0	0	19.1	Titanium	0	0.806
grapple 3	Cylinder	0.254	0.762	0	12.5	Titanium	0	1.1631
battery 1	Cylinder	0.424	0.83	0	161.9	Al 2024-T8xx	0	1.4643
battery 2	Cylinder	0.424	0.83	0	161.9	Al 2024-T8xx	0	1.4643
battery 3	Cylinder	0.29	0.316	0	24.9	Al 2024-T8xx	55.1904	0
acs box 1	Cylinder	0.152	0.254	0	6.4	Al 2024-T8xx	64.7766	0
acs box 2	Sphere	0.146	0	0	4.5	Al 2024-T8xx	52.6298	0
data e box	Cylinder	0.736	1.09	0	106.1	Al 2024-T8xx	43.139	0
acs e box	Cylinder	0.739	1.09	0	69.9	Al 2024-T8xx	59.5379	0
rem adapt	Cylinder	0.635	1.09	0	12.7	Al 2024-T8xx	75.0469	0
elec box 1	Cylinder	0.508	0.533	0	5.9	Al 2024-T8xx	75.2801	0
elec box 2	Cylinder	0.66	1.07	0	13.2	Al 2024-T8xx	74.9313	0
elec box 3	Sphere	0.5	0	0	34	Al 2024-T8xx	0	0.9503
elec box 4	Sphere	0.5	0	0	20.4	Al 2024-T8xx	49.878	0
elec box 5	Sphere	0.177	0	0	22.7	Lead	70.1614	0
Totals:								6.4771

Figure 3.5-2. Output Table for Guideline 7-1

4. SUPPORTING DEBRIS ANALYSIS

The five sections following the "Assessment of Guidelines" offer supporting analysis calculations to be used when a particular program fails to meet the guideline requirements. The following is an explanation of the analysis available.

4.1 Analysis of Debris Released During Normal Operations

This section allows the user to understand what the orbit lifetime will be for debris released during normal operations. For debris that remains in low Earth orbit the orbit lifetime will be controlled by atmospheric drag. However, for debris in highly eccentric orbit, with apogee altitudes above 10,000 km, lunar and solar gravitational perturbations will also affect the orbit.

The outline for the menu options for this section is presented in Table 4-1. The top level menu for this area presents the user with 3 options:

1. Analysis of Orbit Lifetime/Dwell Time Neglecting Lunar/Solar Perturbations (2.1)
2. Analysis of Orbit Lifetime/Dwell Time Considering Lunar/Solar Perturbations (2.2)
3. Analysis of Time to Lower Apogee Altitude Below GEO Altitude (2.3)

The first and second options are for analyzing orbit lifetimes to address Guideline 3-1, and the third option is to address issues related to Guideline 3-2. If the orbits for the program fall below ~10,000 km altitude, option 1, which neglects the effects of lunar and solar gravitational perturbations, would be used. If the orbits reach altitudes above 10,000 km and the program can afford to consider restrictions on launch date and/or time to allow lunar and solar perturbations to help bring the program within guidelines, the user may use option 2. Option 3 is used for objects left in GTO or other highly eccentric orbits passing through LEO.

In considering analysis options for satisfying Guideline 3-1, the objective is always the same: to reduce the lifetime of debris that spends all or part of its time in LEO. To reduce orbit lifetime generally requires that the average rate of orbital energy loss resulting from atmospheric drag be increased. The options in this section of DAS allow the user to pursue several avenues of investigation.

1. Calculate orbit lifetime using a more accurate projection for solar activity. The assessment for the guideline is performed assuming a constant, average level of solar activity (F10 = 130 sfu). However, if the debris will be released during a launch occurring just before a peak in the solar cycle, it may be that an orbit lifetime calculation using the predicted time-dependent solar activity will lead to a shorter orbit lifetime for the debris. If this approach reduces the orbit lifetime sufficiently to bring the program within compliance with the guideline, then no further action is required. However, the program will need to substantiate that its planned launch date is consistent with that used for the assessment.

2. Changing the mission orbit perigee altitude to reduce the orbit lifetime of operational debris. Since the atmospheric density increases rapidly with decreasing altitude, reducing the perigee altitude of the debris orbit can lead to a dramatic reduction in the orbit lifetime.

3. Use lunar/solar perturbations to reduce orbit lifetime. If debris is left in highly eccentric orbit, so that the apogee altitude is above ~10,000 km, lunar/solar gravitational perturbations cause eccentricity changes in the orbit that may lead to a lowering of average perigee altitude and a reduction in orbit lifetime or may lead to the opposite effect - a raising of average perigee altitude and an increase in lifetime. For a program to have the perturbation work to reduce orbit lifetime the launch time, as a function of the time of year, needs to be constrained. The are several options in the DAS to help the user select launch dates and times and to determine the magnitude of the effect for the particular program.

Table 4-1. Outline of Menu Options for Analysis of Debris Released During Normal Operations (Guideline Area 3)

3.0	Analysis of Debris Released During Normal Operations
3.1	Analysis of Orbit Lifetime/Dwell Time Neglecting Lunar/Solar Perturbations
3.1.1	Calculate Total Area-Time/Object-Time Products
3.1.2	Calculate Orbit Lifetime/Dwell Time for a Single Debris Object
3.1.3	Parametric Orbit Lifetime Assessment
3.1.3.1	Calculate Orbit Lifetime/Dwell Time Given Area-to-Mass and Solar Activity
3.1.3.2	Calculate Area-to-Mass Given Orbit Lifetime/Dwell Time and Solar Activity
3.1.3.3	Calculate Solar Activity Given Orbit Lifetime/Dwell Time and Area-to-Mass
3.1.4	Calculate Debris Orbit & Lifetime Given Initial Orbit & Delta-V
3.1.5	Calculate Delta-V Required to Yield Given Orbit Lifetime/Dwell Time
3.1.6	Calculate Decay Orbit/Delta-V Given Initial Orbit Lifetime/Dwell Time
3.2	Analysis of Orbit Lifetime/Dwell Time Considering Lunar/Solar Perturbations
3.2.1	Calculate Debris Orbit Lifetime/Dwell Time
3.2.2	Calculate Orbit Lifetime/Dwell Time Given Initial Orbit/Delta-V
3.2.3	Calculate Orbit Lifetime/Dwell Time Histograms for RAAN/RAS Region
3.2.4	Calculate Perigee Altitude Contours on RAAN/RAS Plane
3.3	Analysis of Time to Lower Apogee Altitude Below GEO Altitude
3.3.1	Calculate Time to Lower Apogee Altitude to 300 km Below GEO Altitude
3.3.2	Parametric Assessment for Lowering Apogee Altitude Below GEO Altitude
3.3.2.1	Calculate Time Given Final Apogee Altitude, Area-to-Mass, Solar Activity
3.3.2.2	Calculate Area-to-Mass Given Time, Final Apogee Altitude, Solar Activity
3.3.2.3	Calculate Solar Activity Given Time, Final Apogee Altitude, Area-to-Mass
3.3.2.4	Calculate Final Apogee Altitude Given Time, Solar Activity, Area-to-Mass

4.2 Analysis of Accidental Explosions/Intentional Breakups

There is no supporting analysis software for this guideline area.

4.3 Analysis of Debris Generated by On-Orbit Collisions

The objective of this section of the software is to allow the user to assess the potential for creating debris as a result of on-orbit collisions. This debris might be created by collision with another relatively large object in orbit or by a spacecraft being damaged so it cannot be controlled and removed from orbit.

The outline for the menu options for this section is presented in Table 4-3. The top level menu has two options:

1. Assessment of Collisions or Near-Misses with Large Debris (5.1)
2. Assessment of Collisions with Small Debris (5.2)

Table 4-3. Outline of Menu Options for Analysis of Debris Generated by On-Orbit Collisions (Guideline Area 5)

5.0	Analysis of Debris Generated by On-Orbit Collisions
5.1	Assessment of Collisions or Near-Misses with Large Debris
5.1.1	Calculate Probability of Collision vs. Orbit Altitude
5.1.2	Calculate Probability of Collision for a Given Orbit
5.1.3	Calculate Number of Near-Misses vs. Orbit Altitude
5.1.4	Calculate Number of Near-Misses for a Given Orbit
5.2	Assessment of Collisions with Small Debris
5.2.1	Calculate Debris Impact Data for Average S/C Cross-Sectional Area
5.2.1.1	Calculate Impact Probability vs. Orbit Altitude
5.2.1.2	Calculate Impact Probability vs. Debris Diameter
5.2.1.3	Calculate Impact Probability vs. Launch Date
5.2.1.4	Calculate Number of Impacts vs. Orbit Altitude
5.2.1.5	Calculate Number of Impacts vs. Debris Diameter
5.2.1.6	Calculate Number of Impacts vs. Launch Date
5.2.2	Calculate Debris Impact Data by S/C Surface Element
5.2.3	Calculate Preliminary Debris Penetration Data by S/C Surface Element
5.2.4	Calculate Debris Penetration Data by S/C Surface Element

The first option, **Assessment of Collisions or Near-Misses with Large Debris**, provides the user with the opportunity to evaluate the risk of catastrophic collision or near-collision during the mission life of the spacecraft. In many cases this will involve potential collision with an object being tracked by the Space Surveillance network. If this risk is unacceptably high, the program may need to consider changing the mission orbit or providing for some means of collision warning with plans to perform collision avoidance.

The second option, **Assessment of Collisions with Small Debris**, will be of particular interest to programs where collisions with small debris may be a source of concern for mission reliability. The user can calculate several different types of estimates of the probability of damage with small debris. The options are

1. Calculate Debris Impact Data for Average S/C Cross-Sectional Area
2. Calculate Debris Impact Data by S/C Surface Element
3. Calculate Preliminary Debris Penetration Data by S/C Surface Element
4. Calculate Debris Penetration Data by S/C Surface Element

In going down this list, each estimate requires more information from the user, but the resulting answers become increasingly better estimates of the probability of damage and/or the extent of damage on the spacecraft. The first option provides the user with an estimate of how frequently the spacecraft will be hit by debris of a given size and requires only a mission orbit, an average size for the spacecraft, and the time for which the calculation is to be performed. The second option requires in addition a geometric description of the spacecraft and a flight attitude and will provide estimates of impact rates or impact probabilities for a specified debris size for each of the spacecraft surface elements. The third option requires limited surface material information and information on the surface structure to provide a rough estimate of penetration probability. The fourth option requires still more materials information and surface geometry information to provide a best estimate of penetration probability using a generalized set of experimentally determined ballistic limit equations. Better estimates require ballistic limit equations for the specific surface materials and surface geometry.

In general a program will work down this list as the spacecraft design develops:

A. Early in the design development, when the program details may be limited to the altitude and inclination of the mission orbit and the general size and shape of the spacecraft, the first option can be used to determine the probability of impact or the rate of impact of debris on the spacecraft as a function of debris size. With this information, a program will know if a debris impact is a significant factor in the development of the design and operational plan for the program.

B. As the spacecraft design begins to mature, the second option may be used to identify the probability of impact or rate of impact on specific surface elements as a function of debris size. With this information, the program can begin to factor in design responses to reduce vulnerability, perhaps by planning to shield certain surfaces or to move sensitive components away from certain surfaces.

C. As the design progresses toward final design, where materials and specific surface configurations are being finally determined, the last two options may be used. The third option executes much faster than the fourth and is useful for helping to decide, for example, whether surfaces should be made slightly thicker or shielded. In approaching a final decision on surface materials and surface configuration, the user may use the last option to evaluate surface penetration using penetration equations.

If there has been a specific problem with debris impact during design development that directs a program to use debris shields, the Debris Assessment Software (specifically this last penetration flux calculation) should be used only to obtain an understanding of the penetration rate through the shielded surface and should not be used to validate a shielding design. To validate a shielding design, contact either the Orbital Debris Program Office at JSC or personnel at other NASA centers familiar with hypervelocity impact effects.

4.4 Analysis of Postmission Disposal of Space Structures

The objective of this section is to support the user in assessing requirements for postmission disposal, with particular emphasis on removal of objects from low Earth orbit by atmospheric drag within the 25 year lifetime as stated in the guidelines.

The options for postmission disposal are:

1. Analysis to Support Guideline 6-1 (Orbits Passing Through LEO) (6.1)
2. Analysis to Support Guideline 6-2 (Orbits Above LEO) (6.2)
3. Analysis to Support Guideline Area 6-3 (Near Circular 12-Hour Orbits) (6.3)

The outline for the menu options for this section is presented in Table 4-4. Programs with mission orbits in or passing through low Earth orbit including geosynchronous transfer orbits, will generally use the first option. Programs with spacecraft in the geosynchronous region will generally use the second option. The last option is for programs with circular semi-synchronous (12 hour) orbits.

The objective of the postmission disposal guidelines is to reduce the probability that upper stages and payloads that have completed their mission will be left in orbits where there can adversely affect other operational spacecraft. There are two options for achieving this objective: either to remove them from orbit in a timely manner or to move them to a storage orbit removed from regions where there are operational spacecraft. Guidelines 6-1a and 6-1c are the two guidelines directed to removing such systems from orbit; the other guidelines are concerned with transferring these systems to pre-planned storage orbits.

The analysis related to Guideline 6-1a is similar to that for guideline area 3. However, for upper stages and payloads in contrast to operational debris there may be some ability to maneuver, so the orbit lifetime analysis in this area is combined with an assessment of maneuver requirements to transfer to a proper disposal orbit.

The DAS assessment for transfer to storage orbits provides the user with information on the maneuver requirements to the storage orbits in terms of velocity change (Δv), propellant mass fraction, and propellant mass. This enables a program to determine whether there will be sufficient resources to transfer to a suitable storage orbit.

Table 4-4. Outline of Menu Options for Analysis of Postmission Disposal of Space Structures (Guideline Area 6)

6.0	Analysis of Postmission Disposal of Space Structures
6.1	Analysis to Support Guideline Area 6-1 (Orbits Passing Through LEO)
6.1.1	Analysis to Support Disposal by Atmospheric Reentry
6.1.1.1	Calculate Maneuver Requirements vs. Apogee/Perigee Altitudes
6.1.1.1.1	Calculate Maneuver Requirements in Terms of Delta-V
6.1.1.1.2	Calculate Maneuver Requirements in Terms of Propellant Mass Fraction
6.1.1.1.3	Calculate Maneuver Requirements in Terms of Propellant Mass
6.1.1.1.4	Calculate Maneuver Requirements in Terms of Specific Impulse
6.1.1.2	Analysis of Orbit Lifetime Neglecting Lunar/Solar Perturbations
6.1.1.2.1	Calculate Orbit Lifetime
6.1.1.2.2	Parametric Orbit Lifetime Assessment
6.1.1.2.2.1	Calculate Orbit Lifetime Given Area-to-Mass and Solar Activity
6.1.1.2.2.2	Calculate Area-to-Mass Given Orbit Lifetime and Solar Activity
6.1.1.2.2.3	Calculate Solar Activity Given Orbit Lifetime and Area-to-Mass
6.1.1.2.3	Calculate Orbit & Lifetime Given Initial Orbit & Delta-V
6.1.1.2.4	Calculate Delta-V Required to Yield Given Orbit Lifetime
6.1.1.2.5	Calculate Decay Orbit/Delta-V Given Initial Orbit Lifetime
6.1.1.3	Analysis of Orbit Lifetime Considering Lunar/Solar Perturbations
6.1.1.3.1	Calculate Orbit Lifetime
6.1.1.3.2	Calculate Orbit Lifetime Given Initial Orbit/Delta-V
6.1.1.3.3	Calculate Orbit Lifetime Histograms for RAAN/RAS Region
6.1.1.3.4	Calculate Average Perigee Altitude Contours on RAAN/RAS Plane
6.1.2	Supporting Assessments for Transfer to Storage Orbit
6.1.2.1	Calculate Maneuver Requirements vs. Apogee/Perigee Altitudes
6.1.2.1.1	Calculate Maneuver Requirements in Terms of Delta-V
6.1.2.1.2	Calculate Maneuver Requirements in Terms of Propellant Mass Fraction
6.1.2.1.3	Calculate Maneuver Requirements in Terms of Propellant Mass
6.1.2.1.4	Calculate Maneuver Requirements in Terms of Specific Impulse
6.2	Analysis to Support Guideline 6-2 (Orbits Above LEO)
6.2.1	Calculate Super-GEO Storage Orbit Maneuver Requirements (Guideline 6-2a)
6.2.1.1	Calculate Maneuver Requirements vs. Apogee/Perigee Altitudes
6.2.1.1.1	Calculate Maneuver Requirements in Terms of Delta-V
6.2.1.1.2	Calculate Maneuver Requirements in Terms of Propellant Mass Fraction
6.2.1.1.3	Calculate Maneuver Requirements in Terms of Propellant Mass

6.2.1.1.4 Calculate Maneuver Requirements in Terms of Specific Impulse
6.2.2 Calculate LEO/GEO Storage Orbit Maneuver Requirements (Guideline 6-2b)
6.2.2.1 Calculate Maneuver Requirements vs. Apogee/Perigee Altitudes
6.2.2.1.1 Calculate Maneuver Requirements in Terms of Delta-V
6.2.2.1.2 Calculate Maneuver Requirements in Terms of Propellant Mass Fraction
6.2.2.1.3 Calculate Maneuver Requirements in Terms of Propellant Mass
6.2.2.1.4 Calculate Maneuver Requirements in Terms of Specific Impulse
6.3 Analysis to Support Guideline Area 6-3 (Near Circular 12-Hour Orbits)
6.3.1 Calculate Maneuver Requirements to Storage Orbit Above SSO (Guideline 6-3a)
6.3.1.1 Calculate Maneuver Requirements vs. Apogee/Perigee Altitudes
6.3.1.1.1 Calculate Maneuver Requirements in Terms of Delta-V
6.3.1.1.2 Calculate Maneuver Requirements in Terms of Propellant Mass Fraction
6.3.1.1.3 Calculate Maneuver Requirements in Terms of Propellant Mass
6.3.1.1.4 Calculate Maneuver Requirements in Terms of Specific Impulse
6.3.2 Calculate Maneuver Requirements to Storage Orbit Below SSO (Guideline 6-3a)
6.3.2.1 Calculate Maneuver Requirements vs. Apogee/Perigee Altitudes
6.3.2.1.1 Calculate Maneuver Requirements in Terms of Delta-V
6.3.2.1.2 Calculate Maneuver Requirements in Terms of Propellant Mass Fraction
6.3.2.1.3 Calculate Maneuver Requirements in Terms of Propellant Mass
6.3.2.1.4 Calculate Maneuver Requirements in Terms of Specific Impulse

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4.5 Analysis of Debris Reentry Risk after Postmission Disposal

The criterion for risk on reentering systems is the potential for human casualty from debris surviving reentry. Consequently, there are two options for reducing this risk: either to have less debris survive reentry or to perform a controlled reentry so that the debris that survives reentry will impact uninhabited areas (oceans). Within DAS debris survivability may be reduced by breaking up a structure at higher altitude and exposing more of the components to aerodynamic heating earlier in the reentry profile or to use materials on the reentering systems that are less survivable. These options may be pursued in the evaluation section of the software. This section is used to assess the option for controlled reentry.

If the user's program violates Guideline 7-1, then this section has options to study requirements for controlled reentry and to perform preliminary calculations on the location of the reentry footprint relative to the reentry maneuver required to control the ground impact point.

The mitigation alternatives that are supported by the software are to control the ground impact point, and this is done by maneuvering to orbits with low enough perigee altitude that the atmospheric reentry point is well determined. The software allows the user to specify the reentry orbit by one of two conditions:

1. Maneuver to Reentry Orbit with Specified Perigee Altitude (7.1.1)

2. Maneuver to Immediate Reentry Orbit with Specified Flight Path Angle (at a Specified Reentry Interface Altitude) (7.1.2)

Each option allows the user to perform assessments to understand the performance requirements for controlling the ground impact point and a plot option to relate the reentry maneuver to the ground impact point.

The outline for the assessment options in this section are provided in Table 4-5.

Table 4-5. Outline of Menu Options for Analysis of Debris Reentry Risk after Postmission Disposal (Guideline Area 7)

7.0	Analysis of Debris Reentry Risk after Post-Mission Disposal
7.1	Analysis to Support Controlled Reentry
7.1.1	Maneuver to Reentry Orbit with Specified Perigee Altitude
7.1.1.1	Calculate Postmission Disposal Maneuver Requirements
7.1.1.2	Calculate Maneuver Requirements vs. Apogee/Perigee Altitudes
7.1.1.2.1	Calculate Maneuver Requirements in Terms of Delta-V
7.1.1.2.2	Calculate Maneuver Requirements in Terms of Propellant Mass Fraction
7.1.1.2.3	Calculate Maneuver Requirements in Terms of Propellant Mass
7.1.1.2.4	Calculate Maneuver Requirements in Terms of Specific Impulse
7.1.1.3	Plot Reentry Ground Footprint
7.1.1.3.1	Define Program Variables
7.1.1.3.2	Plot Preliminary Estimate of Ground Impact Point
7.1.1.3.3	Plot Ground Footprint
7.1.2	Maneuver to Immediate Reentry Orbit with Specified FPA
7.1.2.1	Calculate Postmission Disposal Maneuver Requirements
7.1.2.2	Calculate Maneuver Requirements vs. Apogee/Perigee Altitudes
7.1.2.2.1	Calculate Maneuver Requirements in Terms of Delta-V
7.1.2.2.2	Calculate Maneuver Requirements in Terms of Propellant Mass Fraction
7.1.2.2.3	Calculate Maneuver Requirements in Terms of Propellant Mass
7.1.2.2.4	Calculate Requirements in Terms of Specific Impulse
7.1.2.3	Plot Reentry Ground Footprint
7.1.2.3.1	Define Program Variables
7.1.2.3.2	Plot Preliminary Estimate of Ground Impact Point
7.1.2.3.2	Plot Ground Footprint

5. UTILITY ROUTINES

5.1 Science/Engineering Utilities

The science and engineering utilities section of the software is designed to answer general questions that will come up during debris assessments but that may or may not be answered in other sections of the software. For example, in this area the user can designate a collision probability for the spacecraft and the software will calculate the debris size corresponding to that collision probability.

The science and engineering utilities options are outlined in Table 5-1. The options are divided into three areas:

Orbit Evolution Analysis
Meteoroid/Orbital Debris Impact Probabilities
Delta-V Analysis

The first option allows the user to calculate orbit evolution using several types of user input; the primary focus in this section is orbit lifetime after completion of mission. The options for analysis are:

Calculate Decay Orbit/Delta-V Given Initial Orbit/Lifetime
Calculate Debris Orbit & Lifetime Given Delta-V
Calculate Orbit Lifetime with Time-Varying Solar Activity
Calculate Apogee/Perigee Altitude History for a Specified Orbit

There are two options for calculating debris impact probabilities:

Calculate Debris Size Given Probability of Impact
Calculate Probability of Impact Given Debris Size

The final set of options are for the user to calculate maneuver requirements in terms of Δv and to relate Δv to propellant mass requirements or engine performance conditions. The options in this section are:

Calculate Post-Mission Disposal Maneuver Requirements vs. Orbit Altitude
Calculate Delta-V for Orbit to Orbit Transfer
Calculate Propellant Mass Fraction vs. Delta-V Contours
Calculate Propellant Mass Fraction vs. Specific Impulse
Relate Delta-V/Specific Impulse/Propellant Mass Fraction/Propellant Mass

The last selection places the program in a calculator function mode where three of the variables of Δv, specific impulse, propellant mass, and vehicle mass are specified to calculate the fourth variable.

Table 5-1. Outline of Menu Options for Science/Engineering Utilities

S.0	Science/Engineering Utilities
S.1	Orbit Evolution Analysis
S.1.1	Calculate Decay Orbit/Delta-V Given Initial Orbit/Lifetime
S.1.2	Calculate Debris Orbit & Lifetime Given Delta-V
S.1.3	Calculate Orbit Lifetime with Time-Varying Solar Activity
S.1.3.1	Analysis of Orbit Lifetime Neglecting Lunar/Solar Perturbations
S.1.3.2	Analysis of Orbit Lifetime Considering Lunar/Solar Perturbations
S.1.4	Calculate Apogee/Perigee Altitude History for a Specified Orbit
S.1.4.1	Analysis of Orbit Lifetime Neglecting Lunar/Solar Perturbations
S.1.4.2	Analysis of Orbit Lifetime Considering Lunar/Solar Perturbations
S.2	Meteoroid/Orbital Debris Impact Probabilities
S.2.1	Calculate Debris Size Given Probability of Impact
S.2.2	Calculate Probability of Impact Given Debris Size
S.3	Delta-V Analysis
S.3.1	Calculate Post-Mission Disposal Maneuver Requirements vs. Orbit Altitude
S.3.1.1	Calculate Requirements in Terms of Delta-V
S.3.1.1.1	Calculate Delta-V for Immediate Reentry
S.3.1.1.2	Calculate Delta-V for Targeted Reentry
S.3.1.1.3	Calculate Delta-V for Decay Orbit
S.3.1.1.3.1	Calculate for Specified Lifetime
S.3.1.1.3.2	Calculate for Specified Area-to-Mass
S.3.1.1.3.3	Calculate for a Specified Solar Activity
S.3.1.2	Calculate Maneuver Requirements in Terms of Propellant Mass Fraction
S.3.1.2.1	Calculate Propellant Mass Fraction for Immediate Reentry
S.3.1.2.2	Calculate Propellant Mass Fraction for Targeted Reentry
S.3.1.2.3	Calculate Propellant Mass Fraction for Decay Orbit
S.3.1.2.3.1	Calculate for a Specified Orbit Lifetime
S.3.1.2.3.2	Calculate for a Specified Area-to-Mass
S.3.1.2.3.3	Calculate for a Specified Solar Activity
S.3.1.3	Calculate Maneuver Requirements in Terms of Propellant Mass
S.3.1.3.1	Calculate Propellant Mass for Immediate Reentry
S.3.1.3.2	Calculate Propellant Mass for Targeted Reentry
S.3.1.3.3	Calculate Propellant Mass for Decay Orbit
S.3.1.3.3.1	Calculate for a Specified Orbit Lifetime
S.3.1.3.3.2	Calculate for a Specified Area-to-Mass
S.3.1.3.3.3	Calculate for a Specified Solar Activity
S.3.2	Calculate Delta-V for Orbit to Orbit Transfer
S.3.3	Calculate Propellant Mass Fraction vs. Delta-V Contours
S.3.4	Calculate Propellant Mass Fraction vs. Specific Impulse
S.3.5	Relate Delta-V/Specific Impulse/Propellant Mass Fraction/Propellant Mass
S.3.5.1	Delta-V from Propellant Mass/Specific Impulse/Total Mass
S.3.5.2	Delta-V from Propellant Mass Fraction/Specific Impulse

S.3.5.3	Propellant Mass Fraction from Delta-V/Specific Impulse
S.3.5.4	Specific Impulse from Delta-V/Propellant Mass Fraction
S.3.5.5	Propellant Mass from Delta-V/Specific Impulse/Total Mass
S.3.5.6	Specific Impulse from Delta-V/Propellant Mass/Total Mass
S.3.5.7	Total Mass from Delta-V/Specific Impulse/Propellant Mass

5.2 Data and Screen Management Utilities

The data and screen management utilities: (1) assist in managing the data files created by the user during execution of the software, (2) allow the user to set program defaults to values more suited to the particular program being assessed, (3) allow the user to update and modify the materials data base, and (4) allow the user to set the screen text and background colors. The outline of this software area is presented in Table 5-2.

Table 5-2. Outline of Menu Options for Data and Screen Management Utilities

D.0	Data and Screen Management Utilities
D.1	File Utility Menu
D.2	Save Current User Defaults
D.3	Restore Variables to Programmed Defaults
D.4	Modify Materials Database
D.5	Review Applicability of Materials Data Base - message only
D.6	Change Screen Colors

The file utility menu allows the user to review data files that have been created at the user's request. In the current version of the software, the user cannot delete these files from within the program, but instead must delete from outside the program. The files that are identified by this process are:

(1) files that the user has the option of creating anytime a plot or data table is produced as output. Each time the user produces such output, the software will query whether the user wants to save this output. If the user replies no (the default), the software returns to the compute options menu. If the user replies yes (Y or y), the program will save the output as a plot file written in HPGL or as an ASCII file and the software will give the file a name which is written to the screen. These files may be printed, plotted, and saved for future use.

(2) activity logs that record the user activity during a session. In general, the user will probably not want to save this file, and the default answer to the save query at program termination is to not save the file. However, the user does have the option to save this information,

perhaps so a specific case can be rerun in the future. The software will give this activity log a name and report it to the user during the termination process. If the user encounters difficulty with the program (errors, inadequate range on variables, etc.), it is important to save this file so the problem can be repeated and resolved by the software developers.

The program default values are the values loaded into variable locations during program startup. These are reasonable values that lead to useful output examples. The two choices relating to user defaults allow the user to either change these default values, for example to use the known mission orbit data rather than the default orbits so that the user does not have to change all of the data to the program default values each time the software is run, and to restore the program to the original default values.

The option to maintain the materials data base allows the user to add new materials or modify or add to the data for existing materials. Materials data are used for calculation of debris penetration fluxes and to determine reentry survivability. The option to review the materials data provides the user with a list of the materials in the data base and whether the data for each material are sufficient to support these analysis areas.

5.3 User Help

There are two types of user help provided in the software: the user help messages in this section and the screen-specific user help messages that can be accessed from any of the program menus. The help messages in this area provide general user help for the software as a whole and directions for obtaining additional user help. The on-line user help messages can be retrieved by the user during program execution and are designed to specifically address the menu on the screen. The screen-specific help messages are obtained by entering <alt-H>.

Table 5-3. Outline of Menu Options for User Help Messages

H.0	User Help
H.1	About Program
H.2	Traversing Menus
H.3	Data Entry
H.4	Plot Files
H.5	Table Files
H.6	Data Files
H.7	Additional Help

APPENDIX A
DEBRIS ASSESSMENT SOFTWARE INSTALLATION AND FILE CONTROL INSTRUCTIONS

A.1 INTRODUCTION

This appendix provides the user with guidance and instructions for installing or upgrading the software.

A.2 INSTALLATION INSTRUCTIONS

One can install DAS 1.5 from either a CD-ROM or from the NASA Johnson Space Center Space Science Branch website (www.orbitaldebris.jsc.nasa.gov). There are three files of interest in this matter. These include a compressed file das15cmprss.exe, a READ.ME file and the operator's manual. The operator's manual is available in three versions: a Microsoft Word version (DAS.doc), a PDF version (DAS.pdf) and a plain ASCII text version without figures (DAS.txt). The read.me file gives revision information and instructions for installation. Das15cmprss.exe is a self decompressing file program that will create the DAS directory with all files in the correct locations when executed. To install the program, move the daspkg.exe file into the root directory on your chosen hard disk device. Drives C: or D: are recommended. Then execute the program and the DAS directory system will be created. To run the program go to the das1_5 directory and start the program das.exe.

A.2.1 Systems Required

Das 1.5 runs on Microsoft Windows 95, 98, NT, and Millenium Edition. The expanded directory takes about 10 Megabytes of storage space and the program itself is about 5 Megabytes in size. Das 1.5 requires that the number of monitor colors be set to a higher number of colors than 16 or 256. High Color or True Color are better choices.

The user interface of the program is quite fast and the computational steps take only a few seconds on state of the art machines. Older computers, especially those without a math coprocessor may run slower during large computational steps.

A.3 FILE CONTROL

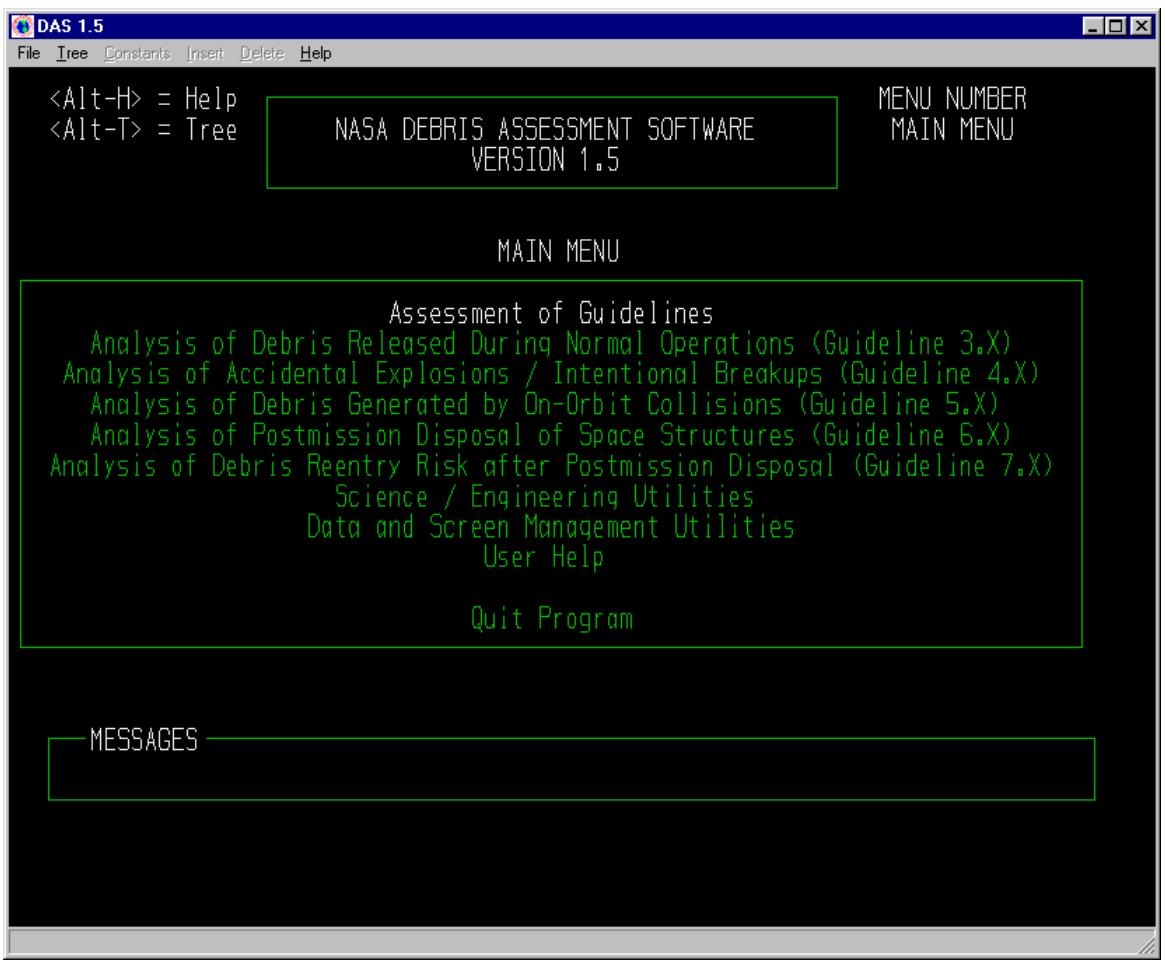
A list of user-generated files that have been saved to the disk can be obtained using the File Management Utilities in the Main Menu. If the user wishes to delete some or all of these files to increase the available disk space, this must be done from the DOS prompt or File Browser such as the Window Explorer outside of the program.

APPENDIX B
RUNNING THE DEBRIS ASSESSMENT SOFTWARE

B.1 INTRODUCTION

If the installation was performed as described in Appendix A, move to the Das1_5 subdirectory and start the program by executing Das.exe. If the program starts appropriately you should see a window with a graphic of the earth and the words "NASA ORBITAL DEBRIS ASSESMENT SOFTWARE - press any key to continue". Press any key or click on the screen and you will progress to another screen with some initial information. Press any key again and you should arrive at the Main Menu, a screen looking like that in Figure B-1.

Figure B-1. DAS 1.5 Entry Level (MAIN) Menu



DAS 1.5 has included a Windows style interface surrounding the old DOS program. Users of DAS 1.0 will find the functionality unchanged. The menu bar at the top of the window provides easy access to commands that previously required special key combinations such as **<alt-H>** for Help. The Print mechanism which did not work properly in DAS 1.0 now works and is available underneath the File menu. Exit is also available under the File menu but it is wiser to exit the program by going to the main menu and selecting the Quit Program item, thus insuring that no files are left open and corrupted.

B.2 USER INTERFACE

The user interface for the software is in the form of a set of screens. The first series of screens form a hierarchy of **SELECTION MENUS** allowing users to select which kind of analysis they wish to perform. The top most menu as seen in Figure B-1 is typical. Then once an analysis is found there is a **COMPUTE MENU** that allows the user to input variable values and compute and display results.

B.2.1 Selection Menus

Selection screen menus consist of a column of options, one of which appears bold or highlighted. The bolded option is the one exercised by the program when the user exits the screen by striking the **ENTER** key. The user selects the option by using the up and down arrow keys to get the desired option to be highlighted; if the mouse driver has been installed by the user, the mouse may also be used to make the selection. The options listed define more specifically the type of analysis to be performed, perform a specified type of analysis, move up one level in the program, or return to the Main Menu. The user returns to the Main Menu to select other types of analysis or the exit the program.

The program is organized in a vertical hierarchical structure with each of the main menu options being the start of an independent analysis module. The user moves down that structure by selecting analysis options or performing analyses and moves up that structure either one level by exercising the option **Move 1 Level Up** or back to the main menu by selecting **Return to Main Menu**. The user can move to another analysis module *only* by returning to the main menu. To help the user keep track of the location within the program, each menu is given a number matching that given in the tables in Sections 3, 4 and 5 of this manual and, in bold just below the program name block, the selection that was made to get that menu. The user may see the path that was followed to get to the current menu by entering **<alt-T>**.

The Main Menu provides options for the type of analysis to be conducted and also allows the user to access general user help messages. The first menu option in the entry menu displays the guideline evaluations that correspond to sections 3 through 7 of the NASA Safety Standard 1740.14. The other options in the entry menu provide supporting analysis for the evaluations. The structure of the program under each option is different, but the structure and choices are easily followed.

A message box is shown at the bottom of each screen. This box is used to provide the user with information such as the valid range of numeric data or prompting messages when the program requires a user response. The user can obtain help information on the current screen by entering **<alt-H>**.

B.2.2 Compute Menus

The user will encounter a compute menu at the end of each string of selection menus. There are two general functions presented in a compute menu: (1) provide user input data and (2) calculate desired output data. User input data may be in the form of single numbers, simple (single entry) data tables, or complex (multiple entry) data tables. Program output may be in the form of a plot file written in Hewlett Packard Graphics Language (HPGL) or in text column delimited data tables. In generating plot data, the user can control the range of dependent and independent variables and the major and minor increments in data values for the X- and Y-axes with the plot control variables. The user can also output results by using the Print feature in the File Menu Bar at the top of the window. It is also worth mentioning that any Microsoft window can be grabbed into any document by selecting it, hitting <alt-print screen>, then moving into any other program and doing a paste. This series of steps moves a screen image of the current window onto the clipboard and then into any program capable of using such screen images. Typical programs that can handle such images include Microsoft Word, Excel and Powerpoint.

Output data tables and plots may be saved for sending to a printer or plotter at the end of the session. Each time the program produces a plot or output table the user will be asked whether this output should be saved. If the user elects to save the data by using the left/right cursor arrows to highlight “yes”, the software will write it as a data file using the naming convention *PLTddmmm.sss* for plot files (written to the PLOT subdirectory) and *TBLddmmm.sss* for tabular output data (written to the TABLE subdirectory). “dd” is the current day of month and “mmm” is the three-letter name of the month; “sss” is a sequence number that begins with 000 for each day. The format of the plot files is HPGL, a Hewlett-Packard plotter format. The format of the tabular data is an ASCII Text file with the tables being column delimited.

Since the user provides all of the input data prior to performing calculations, user input to the program can occur very rapidly for any type of computer being used. If a low performance computer is used, the calculations that follow from the input may take a long time, but it is not necessary to wait at the terminal for results. In most cases where computations may take more than a few seconds a message will be sent to the screen monitoring the progress of the calculations.

To help the user become more familiar with the software, the default variable values can always be used to produce output with no need for the user to change any parameter values

B.2.2.1 Science/Engineering Data Input: Define Program Variables

Scientific or engineering data are entered into the program from a compute menu by selecting **Define Program Variables**. Selecting this option will bring up a menu in which each of the required input parameters is identified by a descriptor line with the current value for that parameter. The line awaiting user input is highlighted or bolded. The user moves between data lines by using the up and down cursor arrows or the mouse. When all data values are correct the user returns to the computation selection menu by striking the **ESC** key.

In the screens where data values are entered, each data line will have a descriptor, current value, and unit. The data values are either the values initialized at program startup or the last values entered by the user. To change data, move to the appropriate line, and either hit return on the keyboard or click on the variable name with the mouse pointer. In either case a subwindow panel will come up where the new value for the variable is to be entered. Type in the variable value and then click on the **OK** button or hit the **ENTER** key to return to the previous window. To have the software initialize to user-specific initial values, the user can redefine the initial values using the option **Save User Default Values** under **Data Management Utilities** in the main menu.

Numerical data may be entered in integer, decimal, or exponential format. If a number is entered without a decimal point, the decimal is assumed in the normal location. That is,. "10" is interpreted as "10.0000" and "9E5" is "9.00E+05". Since all numerical data shown on the screen is in normal floating point format, numbers very near to 0 (e.g. 1.00E-09) may appear as 0 on the screen, but the proper value will be used by the program.

Entering invalid data, numeric data that are out of range or the wrong type of data (e.g., a character string when numerical data are required), causes the data entry subwindow panel to refresh, thus indicating a new data value must be entered. Pressing the **Cancel** button will return to the default value for the variable.

The last line on some science/engineering data entry screens is a simple table - for example, a list of orbit lifetimes used to generate orbit lifetime contours as a function of initial apogee and perigee altitude. A simple table is indicated by two columns, shown as boxes, in which user parameter values can be entered. The user can leave these values unchanged by using the cursor arrow to bypass the data entry line. To enter data, move to the last line on the menu. Type in each data value followed by striking the **ENTER** key. To quit entering data, type "q" and strike the **ENTER** key. Data in a simple table can be removed by exiting the menu and going up one level and returning.

If the last line of input is a multiple column data table, a data table name will appear on the last line of user input. To change the data in this table or to change the name of the data table, highlight the line, enter the appropriate name, and strike the **ENTER** key. The program will query the user whether changes should be made to this table; if so, the table is brought onto the screen and the entries modified using a table editor. The editor commands are shown at the bottom of the table display and allow the user to insert or delete complete records in the table or to make changes to data fields within a record. When changes have been completed in the table, the user will be given the option of saving or replacing the table.

These multiple column data tables are stored as data files in the DATA subdirectory on the user's disk under the name CCCCC.TBL, where CCCCC is the name of the table as used in the program. On exiting from the table editor, if the user elects to save a table under the original name, the program will replace the old data on the user's disk with the revised data; if the user saves the revised data under a new name it will become an additional data file that can be used for future input. If the user wishes to save the table as new data, the name given at the program prompt must consist of no more than 8 characters, and only alphanumeric characters may be used (no special characters such as "." or "$").

Default versions of all complex data tables are supplied with the software under the initial default name encountered in the software. Table B-2 provides a summary of these data files. In general, the user does not require knowledge of the structure of these files, since they are created by DAS. If the user requires such knowledge, to avoid having to enter a large amount of data by hand within the program, for example, this information can be obtained from the NASA Johnson Space Center.

B.2.2.2 Plot Data Input

For analyses that result in plot output, the user is also given the option of modifying the plot by changing the range of values for the dependent and independent variables and by changing the number of major and minor intervals for the two axes. This option is exercised by selecting **Define Plot Variables**. The menu that appears on the screen is shown in Table B-3.

B.2.2.3 Calculate and Present Output Data

After completing the data input, plot or tabular output presentations of the output data are obtained by selecting the option that is most commonly **Display Plot** or, for tabular data, a line descriptive of the type of data table that will be calculated.

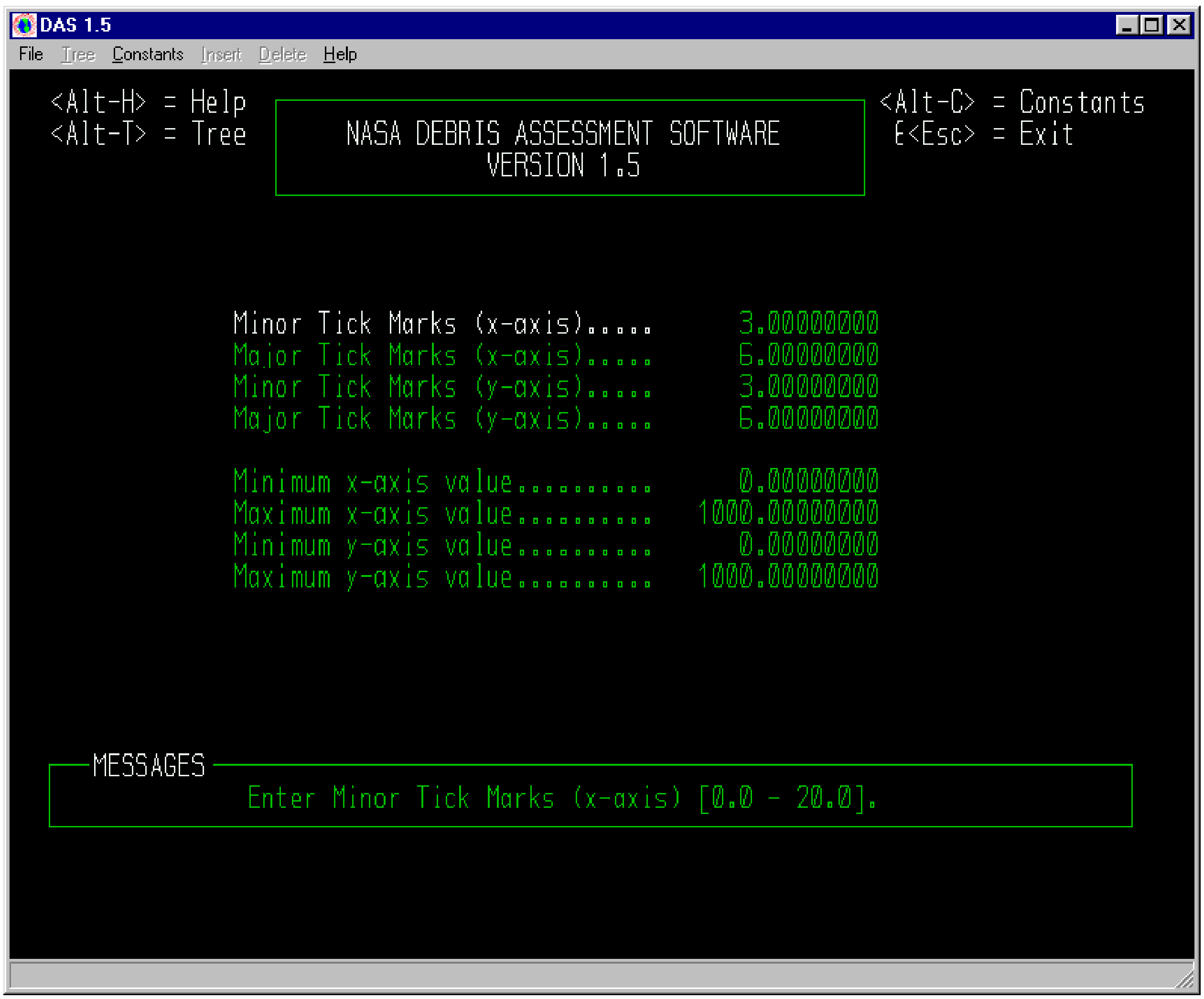
Table B-2. Summary Of User Input Data Tables

Default File Name	Guideline Where File is Used	Description
DEMO3.TBL	Guideline 3.x	Data on operational debris.
DEMO5.TBL	Guideline 5.x	Spacecraft structural description.
DEMO7.TBL	Guideline 7.x	Description of structural components for reentry survivability analysis.
MATDB.TBL		Materials data file (may be changed by the user).
UDEFS.DAT		User default file (may be created by the user).

The plot or tabular data will be displayed on the screen. The session is continued by entering a carriage return, at which time the user will have the option of saving the plot/table to make a hard copy after the completion of the session. The file name under which the data is saved is shown on the screen and is in the form of PLTddmmm.sss or TBLddmmm.sss, where ddmmm is the day and month of the current session and sss is a sequence number. Both plots and tables are self documenting, so the user will be able to identify the parameters that were used to generate the data.

The output plot files are saved to the \PLOT subdirectory below the directory containing the debris assessment executable software, and the table files are stored in the \TABLE subdirectory.

Table B-3. User Input Screen to Specify Plot Format



APPENDIX C

NASA SAFETY STANDARD 1740.14 GUIDELINES

ASSESSMENT OF DEBRIS RELEASED DURING NORMAL OPERATIONS

GENERAL POLICY OBJECTIVE

CONTROL OF DEBRIS RELEASED DURING NORMAL OPERATIONS

NASA programs and projects will assess and limit the amount of debris released in a planned manner during normal operations.

GUIDELINES

3-1. *Operational debris passing through LEO:* For operations leaving debris in orbits passing through LEO, the total amount of debris of diameter 1 mm and larger released during normal operations should satisfy two conditions:

a. The total area-time product should be no larger than 0.1 m^2-yr. The area-time product is the sum over all operational debris of the debris cross-sectional area multiplied by the total time spent below 2000 km altitude during the orbit lifetime of each debris object.

b. The total object-time product should be no larger than 100 object-yr. The object-time product is the sum over all operational debris of the total time spent below 2000 km altitude during the orbit lifetime of each debris object.

Note: Tethers and tether fragments are considered operational debris if left in the environment after mission completion.

3-2. *Operational debris passing through GEO:* For operations leaving debris in orbits passing within 300 km GEO altitude, debris of diameter greater than 5 cm will be left in orbit only if it has a perigee altitude low enough that atmospheric drag will lower its apogee altitude to be no higher than 300 km below GEO altitude within 25 years.

ASSESSMENT OF DEBRIS GENERATED BY EXPLOSIONS AND INTENTIONAL BREAKUPS

GENERAL POLICY OBJECTIVE

CONTROL OF DEBRIS GENERATED BY ACCIDENTAL EXPLOSIONS

NASA programs and projects will assess and limit the probability of accidental explosion during and after completion of mission operations.

GUIDELINES

4-1. *Limiting the risk to other space systems from accidental explosions during mission operations:* In developing the design of a spacecraft or upper stage, each program, via failure mode and effects analyses or equivalent analyses, will demonstrate either that there is no credible failure mode for accidental explosion, or if there are such credible failure modes, will limit through design or operational procedures the probability of the occurrence of such failure modes.
Note: As a quantitative reference, when the probability of accidental explosion can be estimated to be less than 0.0001, the intent of the guidelines has been met.

4-2. *Limiting the risk to other space systems from accidental explosions after completion of mission operations:* All on-board sources of stored energy will be depleted when they are no longer required for mission operations or postmission disposal. Depletion will occur as soon as such an operation does not pose an unacceptable risk to the payload.

ASSESSMENT OF DEBRIS GENERATED BY EXPLOSIONS AND INTENTIONAL BREAKUPS

GENERAL POLICY OBJECTIVE

CONTROL OF DEBRIS GENERATED BY INTENTIONAL BREAKUPS

NASA programs and projects will assess and limit the effect of intentional breakups on other users of space.

GUIDELINES

4-3. *Limiting the long-term risk to other space systems from planned tests:* Planned test explosions or intentional collisions will be conducted at an altitude such that for debris fragments larger than 1 mm: (a) the area-time product does not exceed 0.1 m^2-yr, and (b) the object-time product does not exceed 100 object-yr. No debris larger than 1 mm will remain in orbit longer than 1 year. This guideline is similar to guideline 3-1 for debris generated during normal operations.

4-4. *Limiting the short-term risk to other space systems from planned tests:* Immediately before a planned test explosion or intentional collision, the probability of debris larger than 1 mm from the breakup colliding with any operating spacecraft will be verified to not exceed 10^{-6} immediately after breakup when the debris cloud presents regions of high risk for other space systems.

4-5. *Limiting the risk to other space systems from breakup as a planned reentry procedure:* The planned destruction of a structure as a routine reentry procedure will occur at an altitude no higher than 90 km.

ASSESSMENT OF DEBRIS GENERATED BY ON-ORBIT COLLISIONS

GENERAL POLICY OBJECTIVE

LIMIT THE GENERATION OF ORBITAL DEBRIS FROM ON-ORBIT COLLISIONS

NASA programs and projects will assess and limit the probability of operating space systems becoming a source of debris by collisions with man-made debris or meteoroids.

GUIDELINES

5-1. *Collision with large objects during mission operations:* In developing the design and mission profile for a spacecraft or upper stage, a program should estimate and evaluate the probability of collision with another large object during mission operations.
Note: As a quantitative reference, when the probability of collision with large objects is on the order of or less than 0.001, the intent of the guideline has been met. For programs using tethers, the tether itself need not be considered when estimating the collision probability with large objects.

5-2. *Collision with small debris during mission operations:* In developing the design of a spacecraft or upper stage, a program should estimate and limit the probability of collisions with small debris of size sufficient to cause loss of control to prevent postmission disposal.
Note: As a quantitative reference, when the probability of collision with debris leading to loss of control or inability to conduct postmission disposal is on the order of 0.01 or less, the intent of the guideline has been met.

GENERAL POLICY OBJECTIVE

POSTMISSION DISPOSAL OF SPACE STRUCTURES

NASA programs and projects will plan for the disposal of launch vehicles, upper stages, payloads, and other spacecraft at the end of mission life. Postmission disposal will be used to remove objects from orbit in a timely manner or to maneuver to a disposal orbit where the structure will not affect future space operations.

GUIDELINES

6-1. *Disposal for final mission orbits passing through LEO:* A spacecraft or upper stage with perigee altitude below 2000 km in its final mission orbit will be disposed of by one of three methods:

a. Atmospheric reentry option: Leave the structure in an orbit in which, using conservative projections for solar activity, atmospheric drag will limit the lifetime to no longer than 25 years after completion of mission. If drag enhancement devices are to be used to reduce the orbit lifetime, it should be demonstrated that such devices will significantly reduce the area-time product of the system or will not cause spacecraft or large debris to fragment if a collision occurs while the system is decaying from orbit.

b. Maneuvering to a storage orbit between LEO and GEO: Maneuver to an orbit with perigee altitude above 2500 km and apogee altitude below 35,288 km (500 km below GEO altitude).

c. Direct retrieval: Retrieve the structure and remove it from orbit within 10 years after completion of mission.

6-2. *Disposal for final mission orbits with perigee altitudes above LEO:* A spacecraft or upper stage with perigee altitude above 2000 km in its final mission orbit (except for orbits addressed in guideline 6-3) should be disposed of by either of two methods:

a. Maneuvering to a storage orbit above GEO altitude: Maneuver to an orbit with a perigee altitude above the GEO altitude by a distance of at least 300 km + [1,000 × average cross-sectional area (m^2) / mass (kg)] km.

A program will use the postmission disposal strategy that has the least risk of leaving the vehicle near GEO in the event of a failure during the disposal process. Because of fuel gauging uncertainties near the end of mission, it is suggested that the maneuver be performed in a series of at least four burns which alternately raise apogee and then perigee.

b. Maneuvering to a storage orbit between LEO and GEO: Maneuver to an orbit with perigee altitude above 2500 km and apogee altitude below 35,288 km (500 km below GEO altitude).

6-3. *Disposal for final mission orbits that are near-circular 12-hour orbits:* A spacecraft or upper stage with perigee altitude above 19,900 km (300 km below the altitude for 12-hour circular orbits) and apogee altitudes below 20,500 km (300 km above the altitude for 12-hour circular orbits) should be maneuvered to an orbit with perigee altitude above 2500 km and apogee altitude below 19,900 km or to an orbit with perigee altitude above 20,500 km and apogee altitude below 35,288 km (500 km below GEO altitude).

6-4. *Reliability of postmission disposal operations:* In developing the design of a spacecraft or upper stage, a program will identify and limit all credible failure modes that could prevent successful postmission disposal.

Note: As a quantitative reference, when the probability of successfully performing the postmission disposal maneuver can be estimated to be 0.99 or greater, the intent of the guidelines has been met.

SURVIVAL OF DEBRIS FROM THE POSTMISSION DISPOSAL ATMOSPHERIC REENTRY OPTION

GENERAL POLICY OBJECTIVE

LIMITING THE RISK FROM DEBRIS SURVIVING UNCONTROLLED REENTRY

NASA programs and projects that use atmospheric reentry as a means to remove space structures from orbit at the end of mission life will limit the amount of debris that can survive uncontrolled reentry. If there is a significant amount of debris surviving uncontrolled reentry, measures will be taken to reduce the risk by establishing procedures or designs to reduce the amount of debris reaching the Earth's surface or to control the location of the ground footprint.

GUIDELINE

7-1. *Limit the risk of human casualty:* If a space structure is to be disposed of by uncontrolled reentry into the Earth's atmosphere, the total debris casualty area for components and structural fragments surviving reentry will not exceed 8 m^2. The total debris casualty area is a function of the number and size of components surviving reentry and of the average size of a standing individual. This term is defined more precisely in the method to assess compliance section of this chapter.