

EXHIBIT E

**ORBITAL DEBRIS MITIGATION AND
CASUALTY RISK ASSESSMENT STATEMENT**

Iridium Constellation, LLC ("Iridium Constellation") has contracted with the Boeing Corporation to operate and maintain the IRIDIUM system. In conjunction with this contract, Boeing has secured two separate insurance policies. The first policy which has a term of three years, covers activities relating to operating and maintaining the Iridium MSS system, including the planned maintenance de-orbiting of up to eight (8) space vehicles a year as well as the uncontrolled, natural or spontaneous de-orbiting of any space vehicles. The second policy, which has an 18-month term once triggered, covers activities relating to the planned de-orbiting of the entire constellation as well as the uncontrolled, natural or spontaneous de-orbiting of any space vehicle.

In its order establishing service rules for Mobile Satellite Services operating in the 2 GHz band, the Commission required all pending applicants to submit information describing the debris mitigation strategies that they will employ as well as a casualty risk assessment if planned post-mission disposal involves atmospheric re-entry of spacecraft. *See The Establishment of Policies and Service Rules for the Mobile Satellite Services in the 2 GHz Band, Report & Order*, IB Docket No. 99-81, FCC 00-302, ¶ 138, released August 25, 2000. Although this requirement has not formally been applied to 1.6 GHz MSS system licensees, Iridium Constellation hereby submits information responsive to this requirement.

Specifically, Iridium Constellation submits a copy of a technical analysis of the on-orbit and terrestrial risks from the potential de-orbiting of the IRIDIUM system recently

prepared by NASA for the FCC. *See* Attachment 1. Using the Object Reentry Survival Analysis Tool ("ORSAT"), a program developed jointly by NASA and Lockheed Martin, the NASA study estimates that there is a 1 in 18,406 chance of a casualty, as defined by NASA, from the re-entry of an individual Iridium space vehicle.

Iridium Constellation also submits a copy of a constellation re-orbit plan prepared for it by Boeing. *See* Attachment 2. The constellation re-orbit plan, which is designed to minimize both on-orbit and terrestrial risks, will be reviewed and updated quarterly by Boeing. It assumes that the existing agreement between Motorola and U.S.A.F. Space Command/NORAD allowing both the simultaneous tracking of up to 10 satellites and close approach notification will be extended to Boeing.



National Aeronautics and
Space Administration
Headquarters
Washington, DC 20546-0001

APR 19 2000

Reply to Attn of: GS

1000 APR 21 P 2:22

Christopher J. Wright, Esq.
General Counsel
Federal Communications Commission
445 12th Street, S.W
Washington, D.C. 20554

Dear Mr. Wright:

Pursuant to the March 27, 2000, Agreement Between the Federal Communications Commission and the National Aeronautics and Space Administration Concerning NASA Technical Advice on Deorbit of the Iridium Satellite System (Agreement), I am transmitting herewith NASA's orbital debris technical analysis regarding the potential deorbit of the Iridium satellite system. I am pleased that NASA was able to provide this analysis in a prompt and comprehensive manner, and I trust you will find the analysis informative and useful.

Consistent with Section 8 of the Agreement, NASA does not warrant the information provided therein or its suitability for any particular use. Additionally, the FCC will ensure that the analysis provided by NASA pursuant to the Agreement is appropriately marked with a disclaimer regarding the absence of any such warranty.

Consistent with Section 9 of the Agreement, the FCC may provide this analysis to U.S. Government and non-U.S. Government entities, as it deems appropriate. Transmittal to U.S. Government agencies or employees should include notice of the Section 8 disclaimer, as well as notice that the analysis is not to be disclosed to non-U.S. Government entities without express FCC authorization. Where the FCC determines to provide the analysis to non-U.S. Government entities, the FCC shall require that any such recipient agree in writing to indemnify and hold NASA, its employees, and NASA's contractors and subcontractors, harmless from any claim or judgment arising from the deorbiting and reentry of the Iridium satellite system. Furthermore, certain information contained in the analysis may be proprietary and should be appropriately marked and safeguarded consistent with Section 9 of the Agreement and other requirements of law.

As before, I am pleased that we are able to be of service to you. Please feel free to contact Mr. John Hall of the Office of the General Counsel at 202-358-2432 if there is any further assistance you require.

Sincerely,

Joseph H. Rothenberg
Associate Administrator for Space Flight

Enclosure

DSC Control File No. 300-0199
Approved by: [Signature] Chief of [Department] / [Title]
Date: 4/1/00
Date Due: _____

Section 8 of the Agreement Between the Federal Communications Commission and the National Aeronautics and Space Administration Concerning NASA Technical Advice on Deorbit of the Iridium Satellite System states:

"NASA, in agreeing to provide assistance to the FCC in its efforts to assess the risk of damage from reentry of the Iridium constellation, does not warrant the information provided or its suitability for any particular use."

NASA Administratively-Controlled Information (U.S. Government For Official Use Only)
Contractor Proprietary Information and Predecisional Information

ASSESSMENT OF ON-ORBIT AND TERRESTRIAL RISKS FROM IRIDIUM SPACECRAFT

Nicholas L. Johnson
Chief Scientist and Program Manager

12 April 2000

NOTICE: NASA does not warrant the information contained herein or its suitability for any particular use. Any distribution of this assessment or information contained herein must be appropriately marked with a notice regarding the absence of any such warranty



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Contractor Proprietary Information and
Predecisional Information

Johnson Space Center



Orbital Debris Program Office



PRESENTATION OUTLINE



Orbital Debris Program Office

Johnson Space Center, Houston, Texas

- **Constraints and Caveats**
- **Historical Perspective**
- **Reentry Risk Assessment**
- **Long-Term On-Orbit Risk Assessment**
- **Maneuver Plan Risk Assessment**
- **Summary**



CONSTRAINTS AND CAVEATS



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- **Data Integrity**
 - Assessment results are dependent upon validity of data provided by Motorola
 - No independent verification of data performed
- **NASA and Aerospace reentry risk assessments may differ due to**
 - Input data differences
 - Intrinsic model differences
- **For these assessments, NASA did not introduce any additional conservatism**
- **Reentry and collision risk assessments are inherently imprecise**
 - Random processes (general statistics and Monte Carlo techniques)
 - Spacecraft breakup modeling is not an exact science



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HISTORICAL PERSPECTIVE

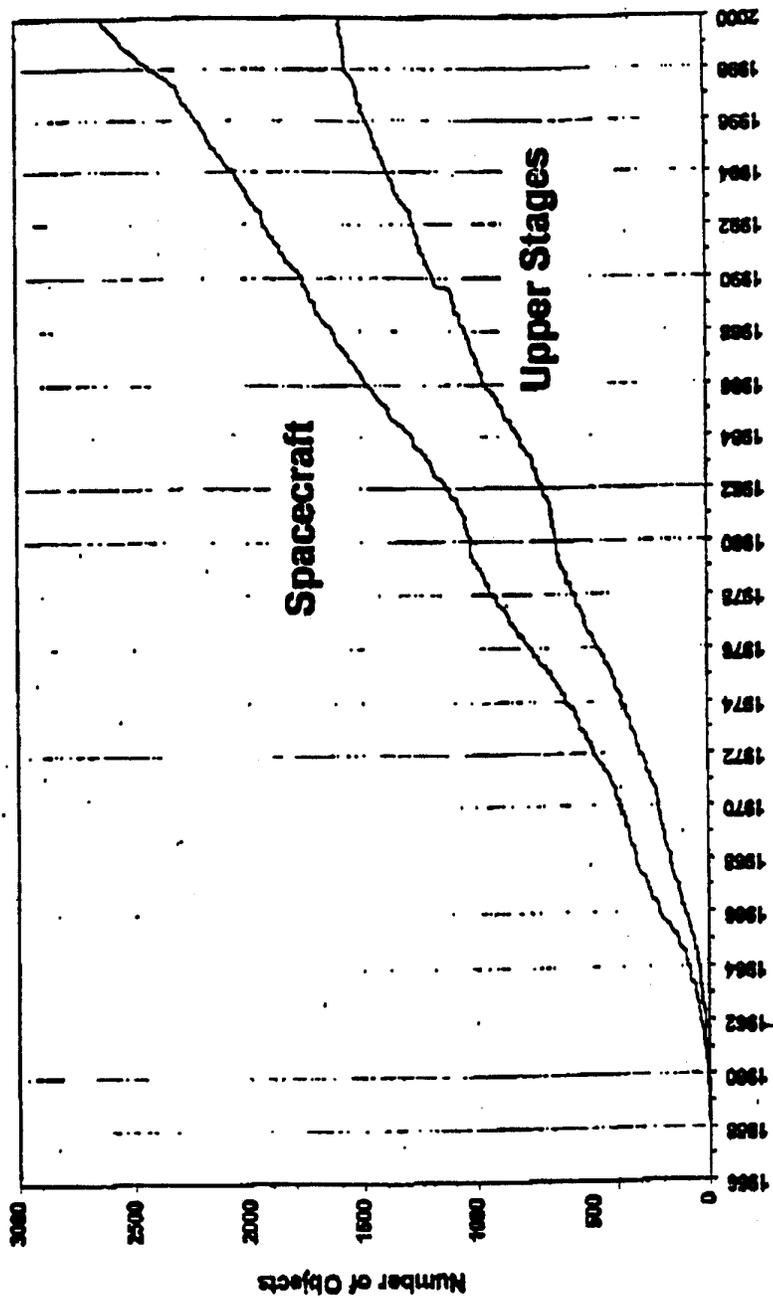


ACCUMULATION OF SPACECRAFT AND UPPER STAGES IN EARTH ORBIT



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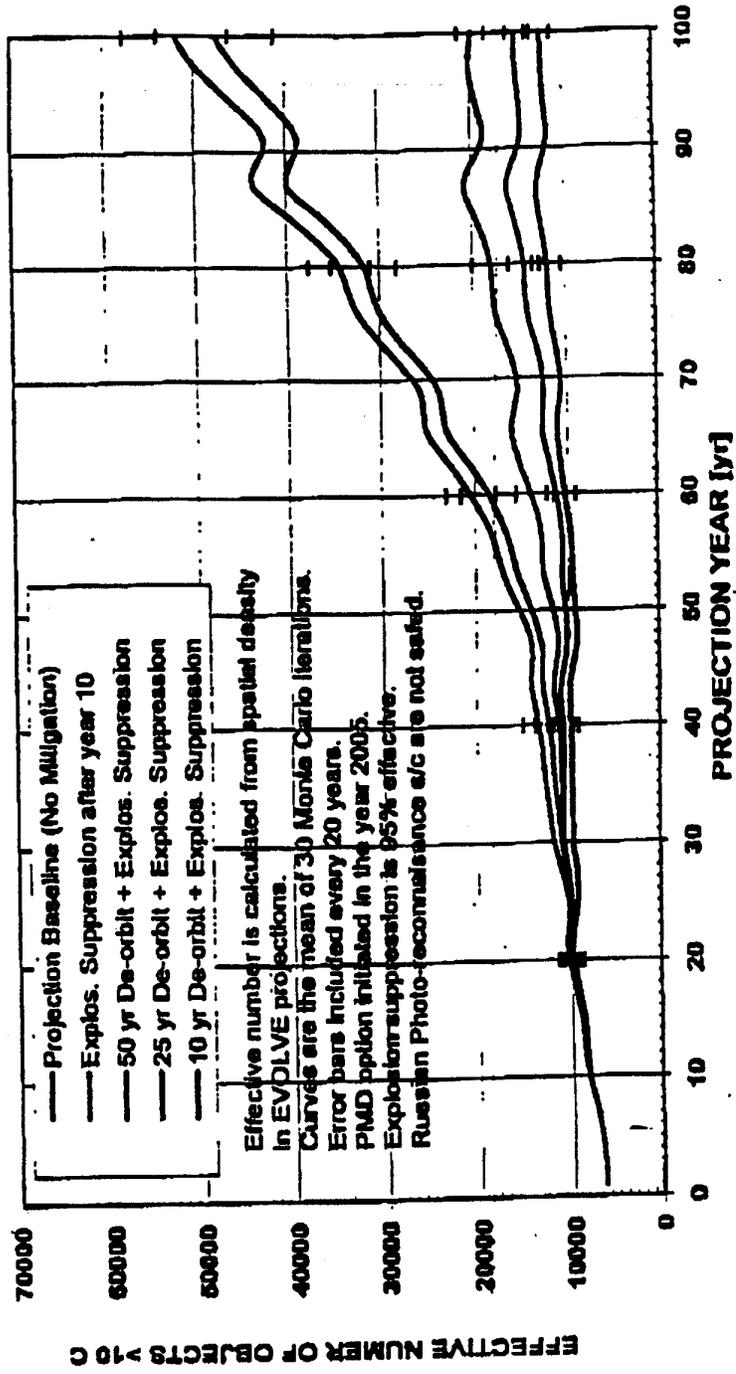


POTENTIAL GROWTH OF EARTH SATELLITE POPULATION

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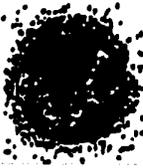
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- To inhibit the growth of the satellite population, US Government orbital debris mitigation standard practices recommend removal of satellites from low Earth orbit within 25 years of mission termination





HISTORICAL CATALOGED SATELLITE REENTRIES

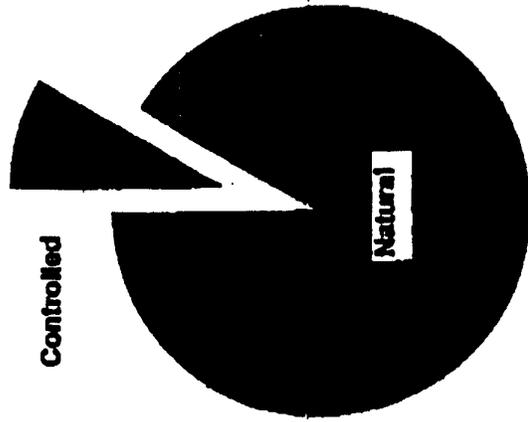


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- **Two types of reentries: Controlled and Natural**
- **Controlled (aka de-orbits)**
 - Human space flight (Mercury, Gemini, Apollo, Shuttle, Vostok, Voskhod, Soyuz, Buran)
 - Human space flight-related (Salyut, Progress, Zond, Bion, Cosmos)
 - Earth observation (Discoverer, Zenit, Yantar, Resurs, FSW)
 - Materials processing (Photon)
 - Other (Gamma Ray Observatory, Gamma, Cosmos)

Controlled



- **Natural (aka decays)**
 - Derelict spacecraft and upper stages
 - Mission-related debris
 - Fragmentation debris
- **Approximately 16,000 (91%) natural reentries to date**



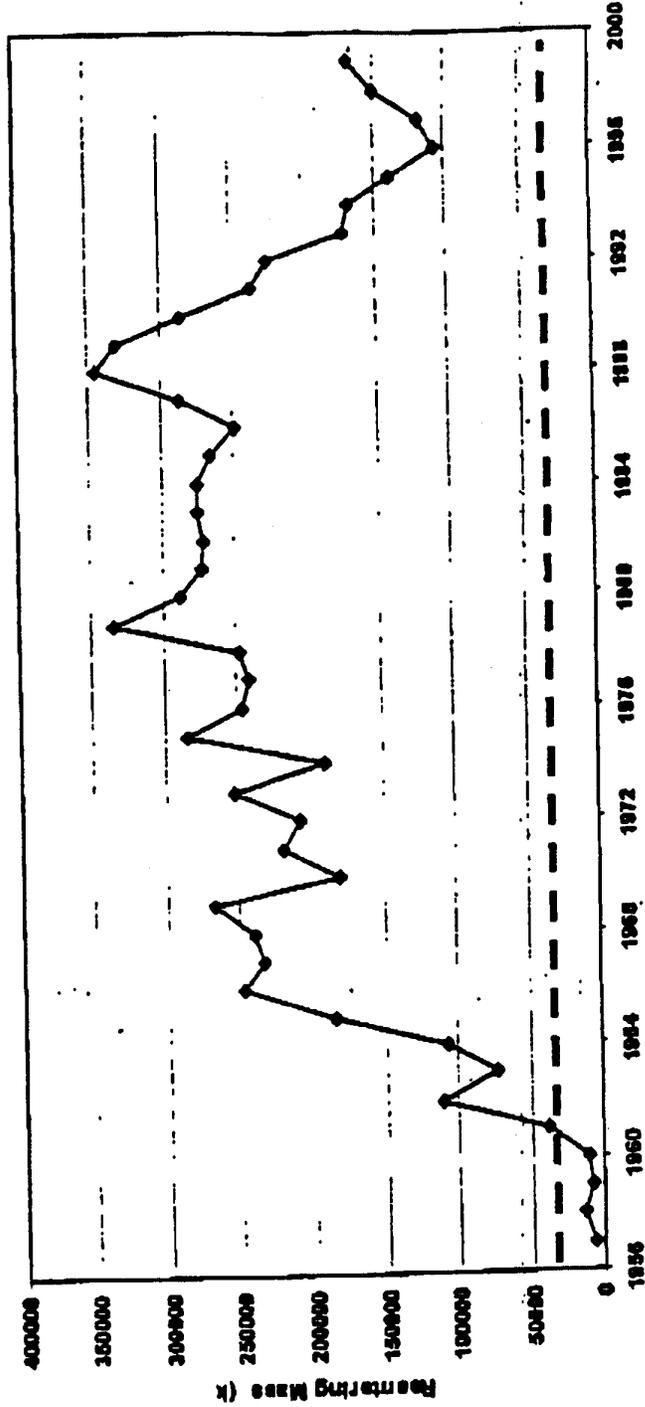
ANNUAL MASS REENTERING NATURALLY



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- Principal influences are Russian launch traffic, solar cycle, and reentry of very large objects



- Total mass of 74 Iridium spacecraft = 41,440 kg



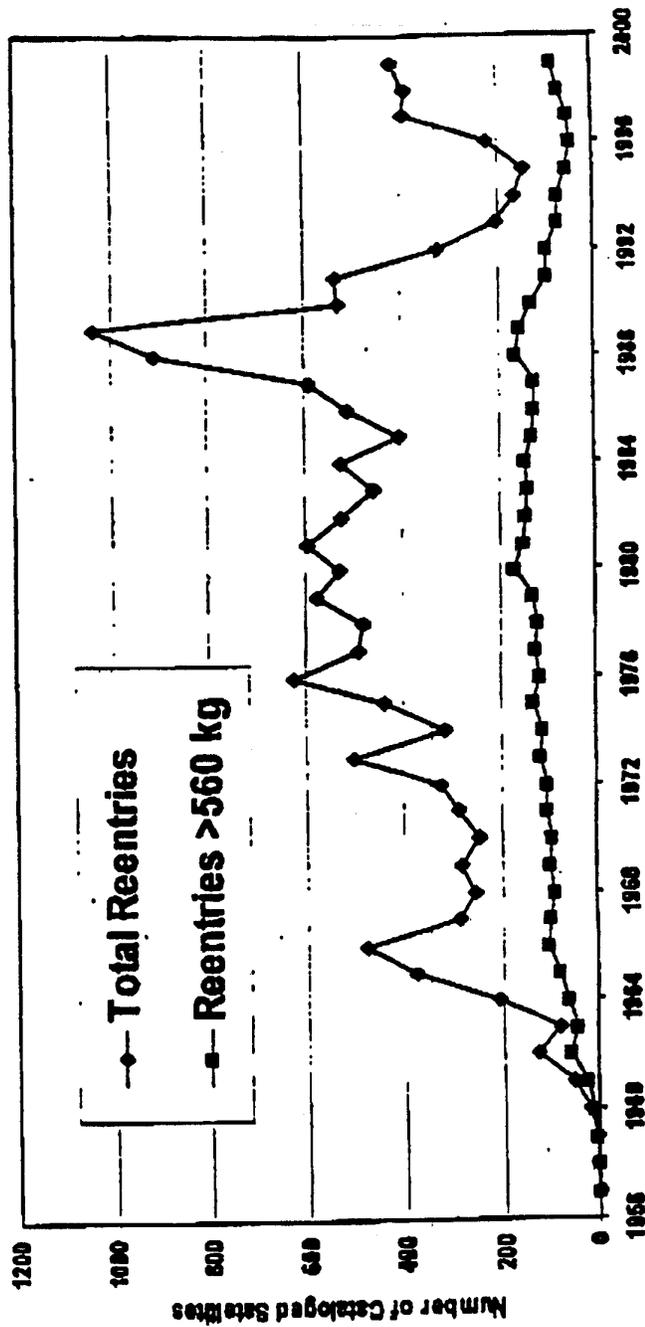
ANNUAL NUMBER OF SATELLITES REENTERING NATURALLY



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- Cumulative number of natural reentries >560 kg: ~4,100
 - ~1,200 Soyuz/Molniya launch vehicle second stages (~2,400 kg each)
 - ~200 Proton launch vehicle third stages (~4,000 kg each)





SATELLITE REENTRIES DURING 1999



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- 12 Controlled reentries
 - 5 human space flight missions (3 Space Shuttle, 2 Soyuz TM)
 - 7 robotic spacecraft (6 Russian, 1 Chinese)
- 421 Natural reentries
 - Total Mass: ~168,000 kg (equivalent mass of 300 Iridiums)
 - 84 Satellites with mass >560 kg; aggregate mass ~163,000 kg
 - 9 spacecraft
 - 75 launch vehicle upper stages and major components



REENTRY OF IRIIDIUM LAUNCH VEHICLE UPPER STAGES



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- **Delta second stage**
 - 10 natural reentries (1997-1999)
 - 9,200 kg reentered
- **Long March CZ-2C second and third stages**
 - 12 natural reentries (1997-1999)
 - Est. 24,000 kg reentered
- **Proton fourth stage**
 - 3 controlled reentries

Total mass of natural reentries = 33,200 kg (59 "Iridiums")



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REENTRY RISK ASSESSMENT



OBJECT REENTRY SURVIVAL ANALYSIS TOOL - ORSAT



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- **ORSAT developed jointly by NASA and Lockheed Martin**
- **Determines whether spacecraft components will demise (burn-up) during reentry or survive to the surface of the Earth**
- **ORSAT Version 5.0 released in 1999**
 - **Results compared with known reentries and the European/Russian Spacecraft Atmospheric Reentry and Aerothmal Breakup (SCARAB) model**
 - **Outputs include casualty area, demise altitude, impact location, impact velocity**
- **Miniature ORSAT (MORSAT) model is a lower fidelity version of ORSAT and is included in NASA Debris Assessment Software (DAS) in support of NASA Safety Standard 1740.14**
- **Higher fidelity ORSAT model was employed in the analysis of the Iridium spacecraft**



CASUALTY AREA



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- **Casualty area is used to assess the risk of any, unsheltered person being struck by falling debris**
- **Casualty area considers both the cross-section of the debris and the cross-section of a person**

$$\text{Casualty Area} = [(\text{Area Person})^{1/2} + (\text{Area Fragment})^{1/2}]^2$$

- **The total casualty area for a reentering satellite is simply the sum of the casualty areas of all the surviving fragments**
- **For an object in an inclination of 86.4° (e.g., Iridium), a casualty area of 11.2 m² is equivalent to a risk of 1 in 10,000 that any person would be struck by surviving debris**



PROBABILITY OF CASUALTY



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- **Probability of Casualty = Casualty area x Population density**
- **A detailed 1994 world population database of 5.622 billion people was scaled to 6.0 billion people to reflect the current world population**
- **The average population density (people per m²) seen by a satellite in a 86.4° inclination orbit was calculated to be 8.92×10^{-6} people per m²**
- **For multiple, identical reentries,**

$$\text{Probability of Casualty} = 1 - (1 - P_o)^N$$
, where P_o = Probability associated with a single reentry
 N = number of reentries
- **Risk may be expressed as a probability ratio by inverting the probability casualty, e.g., $0.00025 = 1$ out of 4,000**



ORSAT EVALUATION OF IRIDIUM SPACECRAFT



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- 47 component types were modeled
 - 103 total components per spacecraft
- Descriptions of each component (including dimensions, mass, and material type) were provided by Motorola
- 6 components (4 types) were found likely to survive reentry
- Several other components appeared to survive in the initial analysis but were found to demise when more detailed construction information was received.



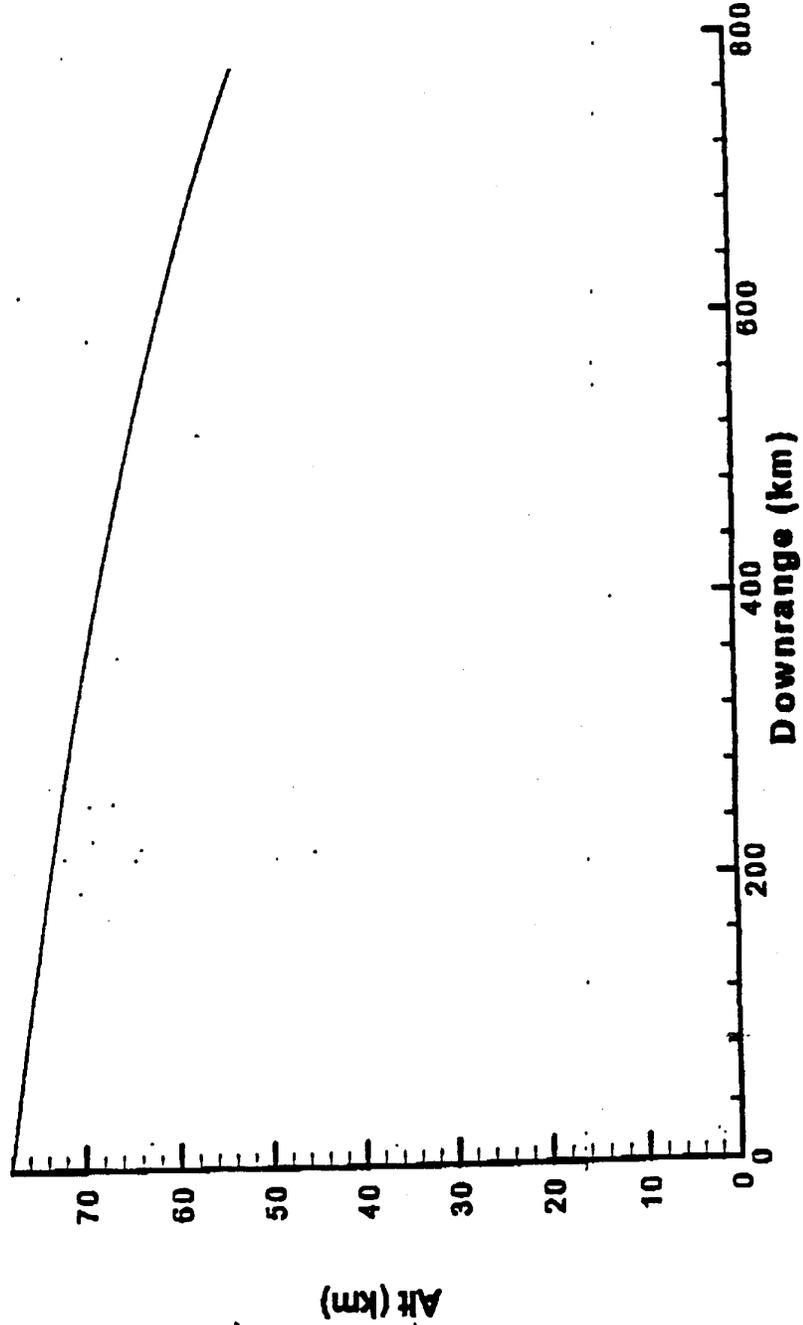
SAMPLE IRIIDIUM COMPONENT DEMISE: SOLAR ARRAY DRIVE ASSEMBLY



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Orbital Debris Program Office

Altitude vs. Downrange from 78 km Break-Up
Altitude for Demising Iridium SADA-1



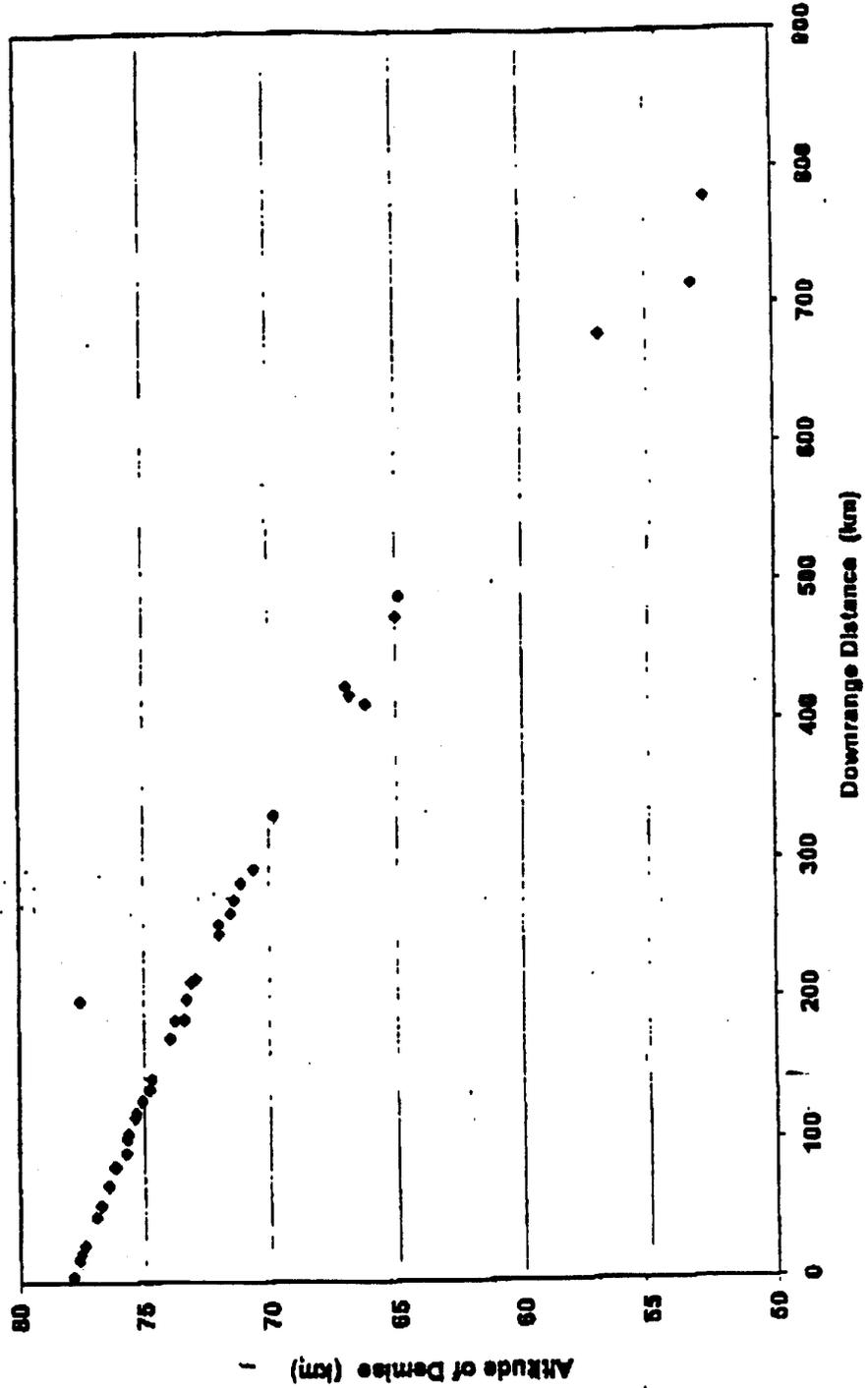


DEMISE ALTITUDES OF IRIDIUM COMPONENTS



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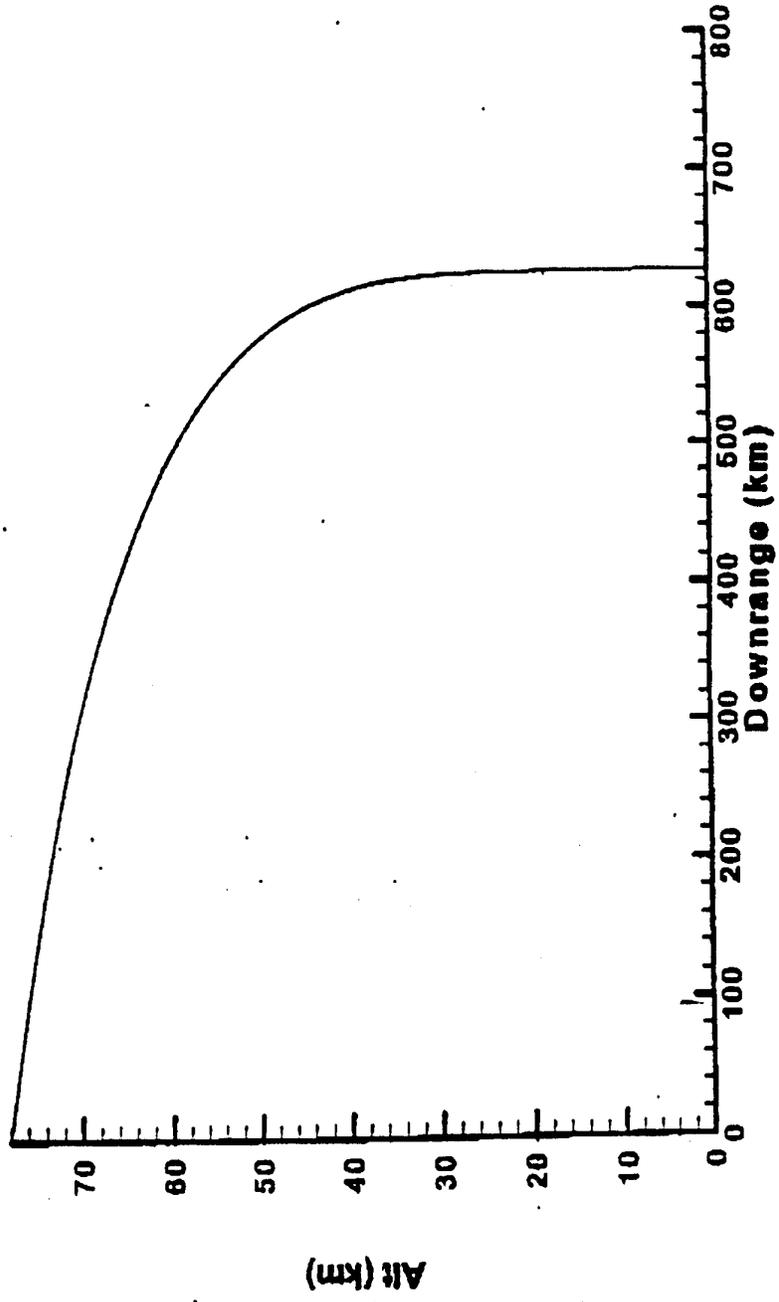
SAMPLE IRIIDIUM SURVIVING COMPONENT: PROPELLANT TANK



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Altitude vs. Downrange from 78 km Break-Up Altitude
for Surviving Iridium Propellant Tank





SUMMARY OF IRIDIUM SURVIVING COMPONENTS



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Item No.	Component	Total Debris		Original Total Mass (kg)	Impact Velocity (mph)
		Casualty Area (m ²)	Area (m ²)		
11	Sep Foot	1.4	6.3	130	
	Bracket (3)				
27	Propellant Tank	1.3	9.8	50	
39	Battery	1.0	30.5	125	
42	Electronic COM Panel	2.3	115.9	45	
			6.1 m ²	162.5 kg*	

* surviving mass will normally be less

• Probability of Casualty for 1 Iridium = 5.43×10^{-5} or 1 in 18,405

• Probability of Casualty for 74 Iridiums = 4.01×10^{-3} or 1 in 249



COMPARATIVE SATELLITE SURVIVAL ASSESSMENTS

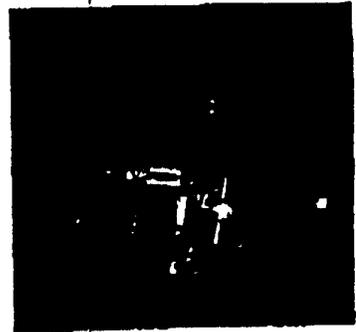


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<u>Spacecraft</u>	<u>Total Mass. kg</u>	<u>Est. Surviving Mass. kg (%)</u>
Mir/Progress M	140,000	30,000 (20%)
Skylab	74,800	18,200-22,700 (24-30%)
Gamma Ray Obs.	13,700	5,800 (42%)
Delta 2nd stage	920	340 (37%)
Iridium	560	163 (29%)

• Total mass reentering naturally through 1999: ~8,600,000 kg





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LONG-TERM ON-ORBIT RISK ASSESSMENT



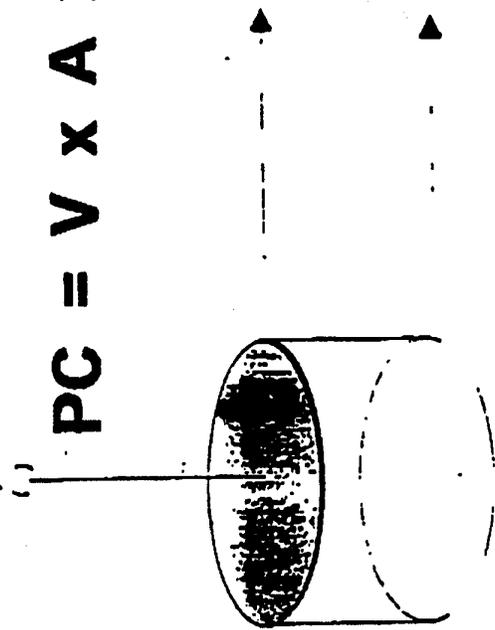
CALCULATION OF ON-ORBIT PROBABILITY OF COLLISION



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Johnson Space Center, Houston, Texas

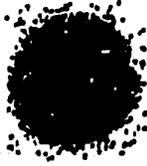
$$PC = V \times A \times S \times T$$



- PC = Probability of Collision**
- V = Relative Velocity**
- A = Cross-sectional Area**
- S = Spatial Density (objects per unit volume)**
- T = Time**



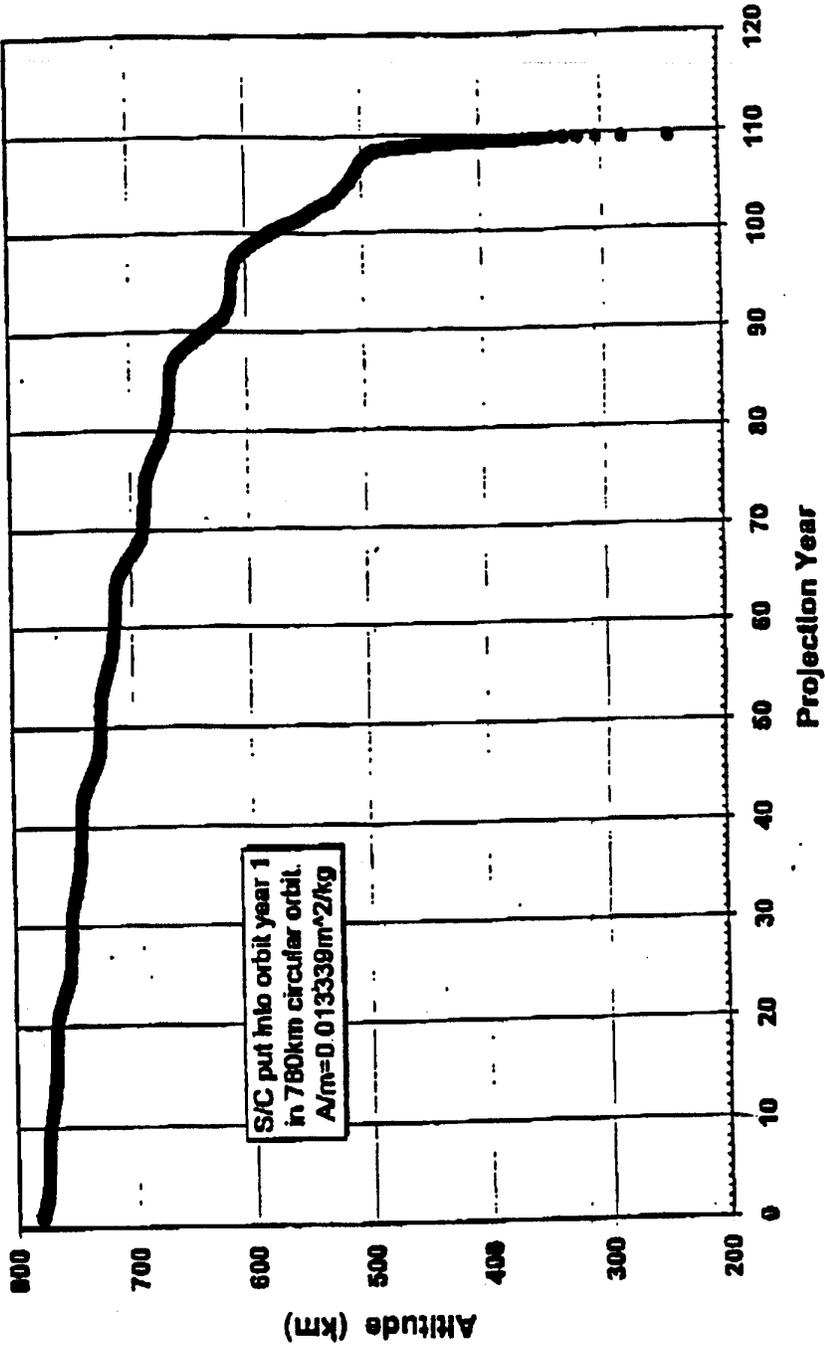
ORBITAL LIFETIME OF PASSIVATED IRIIDIUM SPACECRAFT



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- Solar Cycles 20 and 21 repeated through projection period





PROBABILITY OF COLLISION FOR AN IRIIDIUM SPACECRAFT



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- **NASA's long-term satellite environment model EVOLVE (Version 4.0) was used to determine the probability of Iridium collisions with other cataloged objects during natural orbital decay**

- **The future environment was projected for 108 years assuming launch traffic similar to that of the past eight years and assuming no further adoption of debris mitigation measures (e.g., no suppression of explosions or 25-year rule)**

- **30 Monte Carlo executions of EVOLVE were performed to develop an average collision rate**

- **Results:**

- **Probability of one collision for 1 Iridium spacecraft: 1 in 168**
- **Probability of one collision for 74 Iridium spacecraft: 1 in 3**



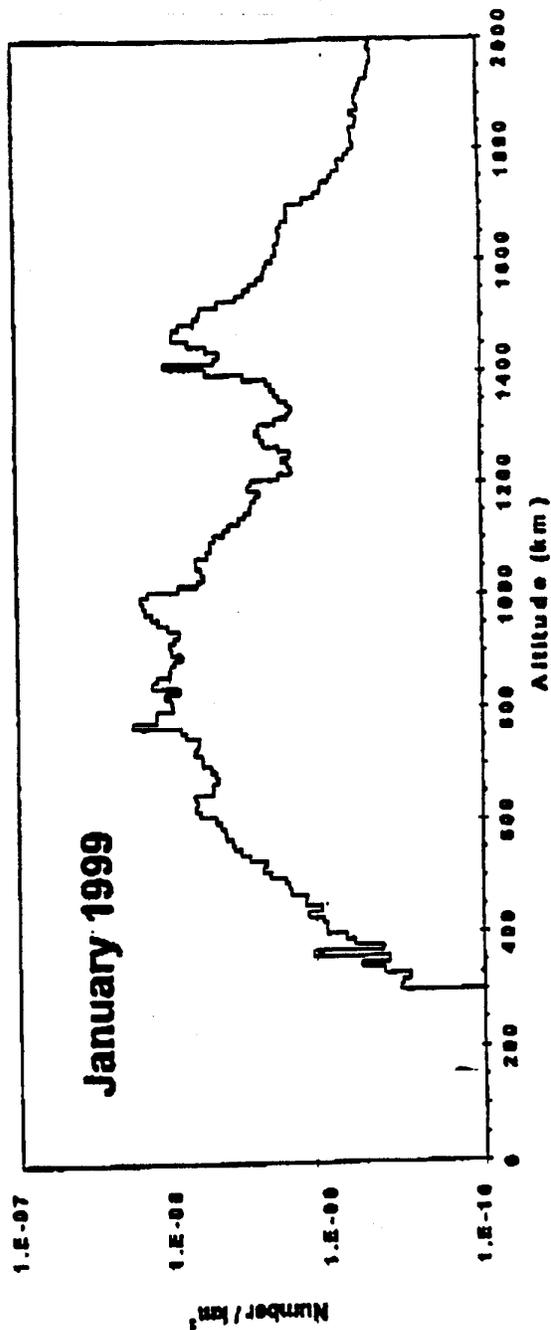
ASSESSMENT OF OPTION OF MANEUVERING TO HIGHER ORBIT



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- **Spacecraft design limits the ability of the vehicle to transfer to a higher storage orbit**
 - Attitude control sensors
 - Radiation hardness
- **With no constraints other than propellant, spacecraft could not reach sufficiently higher altitude for risk benefit**





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MANEUVER PLAN RISK ASSESSMENT



NASA-DOD CONJUNCTION ASSESSMENT CAPABILITIES



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- **Prior to 1998, Space Shuttle collision avoidance decisions relied upon use of U.S. Space Command's COMBO (Computation of Miss Between Orbits) program with the establishment of a keep-out box around the Space Shuttle: 4 km by 10 km by 4 km**
 - Penetration of box inferred a risk of collision of 1 in 100,000 or greater

- **NASA and DoD jointly developed a new conjunction assessment tool to support International Space Station (ISS)**
 - **Special ASW workstation (formerly known as OSW) in Cheyenne Mountain determines conjunction parameters with uncertainties which, in turn, allow NASA JSC personnel to calculate collision probabilities**
 - **ASW is used to support conjunction assessments for ISS and other high-value U.S. space assets**
 - **Process requires man-in-the-loop; only two workstations (prime and backup) available**



BASIC MOTOROLA MANEUVER PLAN

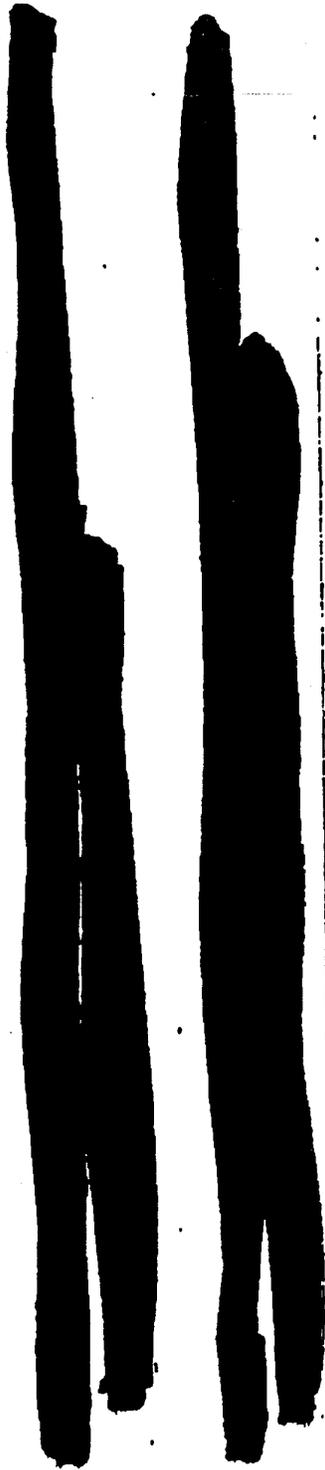


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• Maneuver Sequence

- Lower functional spacecraft to 750 km circular orbit
- Lower perigee to 250 km (i.e., 250 km by 740 km orbit)
- Lower apogee as far as possible with remaining propellant



- Key issue: Position uncertainty of Iridium spacecraft



MAJOR MANEUVER PLAN ISSUES REMAINING TO BE RESOLVED



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- **Expected dispersions (errors) associated with each Iridium engine burn**
- **Keep-out region needed to be established around spacecraft to be protected**
 - **Level of acceptable risk**
 - **Hardware/manpower constraints in Cheyenne Mountain**
- **Selection of spacecraft to be protected**
 - **All resident space objects**
 - **Space Shuttle, ISS, Mir**
 - **NASA robotic spacecraft (HST, CGRO, etc.)**
 - **Other U.S. national assets**
- **Accuracy with which Motorola can determine and predict the location of each maneuvering Iridium spacecraft**



MAJOR MANEUVER PLAN ISSUES REMAINING TO BE RESOLVED (cont.)



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- **Update frequency of maneuver plan and position information from Motorola to Cheyenne Mountain**
- **Procedures for suspending/revising maneuver plan if violation of keep-out zone is identified**

After agreement is reached on maneuver plan, Motorola proposes disposing of 3 spacecraft to test procedures



ASSESSMENT OF REENTRY TARGETING OPTIONS



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- From a disposal orbit of 250 km by 740 km, natural reentry of an Iridium spacecraft should occur within a few months
- The probability of reentry occurring in the Northern or Southern Hemispheres can be influenced slightly by proper selection of latitude of perigee of the final disposal orbit (spacecraft/orbit dependent)
- The probability of reentry into a particular hemisphere could be enhanced if the perigee of the final disposal orbit was lower
- Iridium attitude control system limitations appear to prevent the use of perigees lower than 250 km



SUMMARY



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- With the information currently available, the probability of someone being struck by surviving Iridium debris is assessed to be 1 in 18,405 per reentry and 1 in 249 for all 74 spacecraft combined
- The probability of collision between an Iridium spacecraft and another cataloged space object during natural decay (est. 108 years) is 1 in 168 or 1 in 3 for all 74 Iridium spacecraft combined
- The future (~Year 2100) reentry risks will increase somewhat due to anticipated greater world population
- Maneuvering spacecraft to higher orbits, if possible, leads to a greater risk of on-orbit collisions and a resultant increase in orbital debris
- Proposed disposal maneuver plan requires further assessment and coordination among Motorola, DoD, and NASA



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BACKUP SLIDES

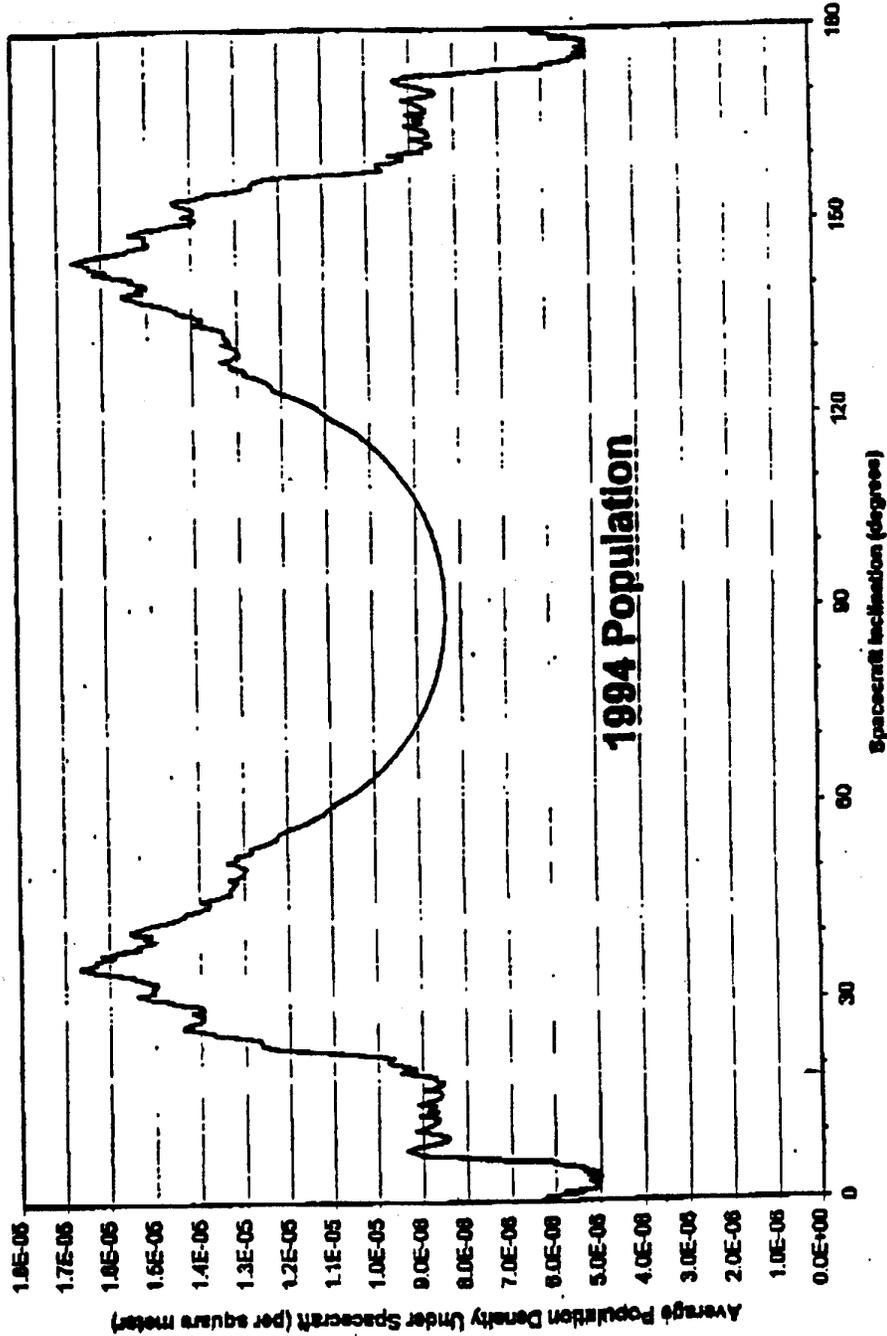


POPULATION DENSITY AS A FUNCTION OF ORBITAL INCLINATION



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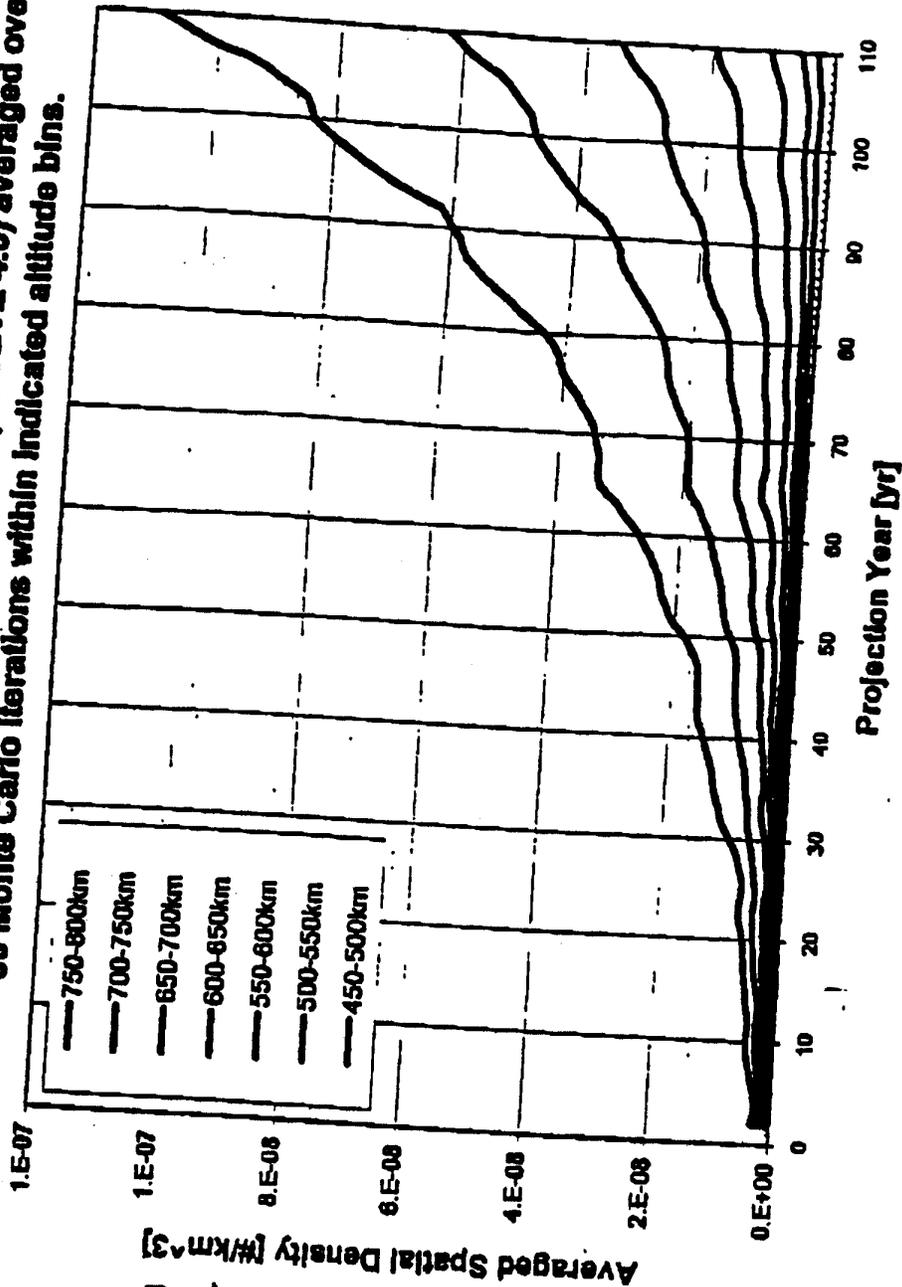


GROWTH OF SPATIAL DENSITY BY ALTITUDE REGIME

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Spatial densities of objects 0.10-0.178m (EVOLVE 4.0) averaged over 30 Monte Carlo iterations within indicated altitude bins.



BOEING PROPRIETARY

REVISION			
REV	DESCRIPTION	DATE	APPROVED
V1	Level 3 Initial Release	03/14/01	

IRIDIUM CONSTELLATION DEBOOST
 PLAN

APPROVED:

Jim Compton
 IRIIDIUM Operations Program Manager

Bernie McCormick
 Chief Engineer

Ed Fleming
 Boeing Deboost Team

Ahsen Abbasi
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 Boeing Deboost Team

Pete Fardelos
 Boeing Deboost Team



Total No. Pages: 9	
DOCUMENT ID PLA-00001-IR	No. of Last Page: 6

File name: (Deboost_Plan)

BOEING PROPRIETARY

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 8.3 General Policy Objective - Limiting the Risk from Debris Surviving Uncontrolled Reentry 5

 8.3.1 Guideline 7-1. *Limit the risk of human casualty.* 5

9. Deboost Plan Updates 6

1. PURPOSE

This document specifies the process to be used for the deboosting of the full IRIDIUM constellation. This includes the goals for deboost, SV groupings, a generic timeline, and a list of daily activities.

2. SCOPE

This document applies to the deboost and decommissioning of the full IRIDIUM constellation, and although parts of the document are applicable to a "single SV" deboost, this document is not intended to specifically cover that case.

3. REFERENCES

3.1 Boeing Internal References

Document Title	Document Number
Communication with US Government Agencies	PRO-00004-IR
Constellation Deboost Checklist	PRO-00002-IR
Deboost Conjunction Notification and Escalation Guide	MAN-00005-IR
Deboost Passivation Sequence	GEN-00006-IR
Deboost Satellite Groupings	GEN-00003-IR
Deboost Document and Procedure List	GEN-00008-IR
SV Lifecycle Configuration Changes	GEN-00007-IR

3.2 External References

- Guidelines and Assessment Techniques for Limiting Orbital Debris (NASA Safety Standard 1740.14, August 1995)
- Assessment of On-Orbit and Terrestrial Risks from IRIDIUM Spacecraft (Johnson Space Center, April 2000)

4. DEFINITIONS/ACRONYMS

DNE: Do Not Erase

GEO: Geosynchronous Earth Orbit

LBCS: Lockheed Bus Control Software

LEO: Low Earth Orbit

OA: Orbit Adjust

Deboost: The process of intentionally lowering the orbits of the entire IRIDIUM constellation.

SOH: State of Health

SV: Space Vehicle

TSB: Telemetry Storage Buffer

WDT: Watchdog Timer

5. DEBOOST OBJECTIVES

5.1 Meet Indemnification Time Constraints

Deboost activities will be scheduled such that all operational IRIDIUM satellites will be commanded to deboost so that they will re-enter before the expiration of any applicable insurance coverage.

5.2 Meet U.S. Government Guidelines

The deboost process will be designed to meet applicable U.S. Government guidelines for Debris Mitigation as identified in the NASA Safety Standard 1740.14, August 1995 (see section 8).

5.3 Communicate with External Agencies

Boeing operations personnel will communicate with appropriate external agencies as required throughout the deboost process. The list of external agencies and contact information will be maintained in a separate document. This document is proprietary and distribution will be limited to persons on a need-to-know basis.

6. DEBOOST PROCESS FLOW

6.1 Overall Process

Upon receipt of direction from IRIDIUM Satellite LLC or as dictated by contractual obligations, Boeing will perform the following activities:

1. Notify external agencies that deboost will commence as defined in the "Communication with US Government Agencies" (PRO-00004-IR).
2. Shut down L-Band constellation-wide.
3. Review SV grouping plan documented in "Deboost Satellite Groupings" (GEN-00003-IR).
4. Generate a detailed schedule for deboosting all satellites.
5. Implement deboost plan.
6. Notify external agencies that deboost is complete.

6.2 Process for deboosting a Single Satellite

There are three phases for deboosting a single satellite:

1. Pre-Deboost Tasks.
2. Deboost Operations.
3. Post-Passivation Activities.

6.2.1 Pre-Deboost Tasks

The tasks performed during the Pre-Deboost phase are:

1. Request Ground and Satellite products.
2. Hold Technical Exchange / Build Content Meeting.
3. Build products.

4. Verify products.
5. Hold Go/No Go Meeting.
6. Product delivery.
7. Perform Mission Planning.
8. Install products on ground system.
9. Load Products to SV.
10. Notify external agencies.

6.2.2 Deboost Operations

1. Perform Mission Phase Change.
2. Perform Mission Constellation Collision Avoidance (Mission vehicles only).
3. Perform Perigee Lowering.
4. Perform Manually Planned Final Orbit Adjustments.
5. Command Satellite to perform Passivation.

6.2.3 Post-Passivation Activities

1. Perform Ground System Cleanup.
2. Prepare Lessons Learned Report.
3. Modify Deboost Plan as Required.

The detailed steps for deboosting a single SV are described in “Constellation Deboost Checklist” (PRO-00002-IR). The satellite configuration changes required for deboost are described in “SV Lifecycle Configuration Changes” (GEN-00007-IR).

6.3 Daily Activities

The following activities will be performed daily during deboost. All nominal activities will be scheduled through Mission Planning Process. Off-nominal activities will be coordinated via Ground Anomaly Meetings.

Table 1 . Daily Deboost Activities

Activity	Frequency
SV Ephemeris Message Load	1x per day per SV
SV Clock Adjust	2x per day per SV
Dump DNE Memory	1x per day per SV
TSB download, OA History download, WDT reset, perform SOH	Every Pass for each SV
Coordination with External Agencies	As defined in the “Communication with US Government Agencies” (PRO-00004-IR) and “Deboost Conjunction Notification and Escalation Guide” (MAN-00005-IR)

6.4 Deboost Groupings

Deboost groupings will be determined based on satellite health and operational considerations to maximize the probability of a successful constellation deboost before the expiration of insurance coverage. The order and grouping of satellites for deboost are specified in "Deboost Satellite Groupings" (GEN-00003-IR). The deboost groupings may be modified during the execution of the deboost plan to address hardware failures or for operational considerations.

7. DEBOOST OPERATIONS

7.1 Mission Constellation Collision Avoidance

During Mission Constellation Collision Avoidance, the SV will complete a series of burns that lower both apogee and perigee such that the orbit will be reduced to approximately 750 km x 750 km. The objective of this phase is to lower apogee/perigee to minimize the collision risk with Mission SVs. This set of maneuvers is not required for satellites in storage orbits. The daily activities specified in Table 1 will be performed.

7.2 Perigee Lowering

During Perigee Lowering, the SV will complete a series of planned maneuvers designed to lower perigee to 250 km. The daily activities specified in Table 1 will be performed.

7.3 Manually Planned Final Orbit Adjustments

During Manually Planned Final Orbit Adjustments, the SV will be commanded into manual OA Planning mode. The SV will be commanded to perform maneuvers to further reduce apogee and/or perigee, until a pre-determined minimum propellant level is reached.

7.4 Passivation

After all maneuvers are complete, commands will be sent to passivate the SV. The passivation will inert the SV, to the extent possible, by removing all stored energy via:

- Re-orienting the solar arrays such that the battery will completely discharge itself, and
- Venting any remaining propellant.

The SV will no longer be controlled or tracked after the passivation. The passivation procedure is described in "Deboost Passivation Sequence" (GEN-00006-IR).

8. COMPLIANCE WITH NASA SAFETY STANDARD 1740.14

NASA Safety Standard 1740.14, August 1995 (Guidelines and Assessment Techniques for Limiting Orbital Debris) establishes guidelines for:

- Limiting the generation of orbital debris.
- Assessing the risk of collision with existing space debris.
- Assessing the potential of spacecraft-generated debris fragments to impact the Earth's surface.

Boeing's objective is to meet relevant guidelines pertaining to post-mission disposal of spacecraft, as described below.

8.1 General Policy Objective - Control of Debris Generated by Accidental Explosions

This General Policy Objective includes guidelines 4-1 (Limiting the risk to other space systems from accidental explosions during mission operations), and 4-2 (Limiting the risk to other space systems from accidental explosions after completion of mission operations). Guideline 4-1 applies only during mission operations and is not covered in this document. Guideline 4-2 does apply to deboost operations.

8.1.1 Guideline 4-2. *Limiting the risk to other space systems from accidental explosions after completion of mission operations.*

This guideline states, "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." This guideline is satisfied at the end of the deboost process by commanding all SVs to execute the passivation sequence. (The passivation sequence reorients the solar arrays to cause battery depletion, and vents remaining fuel from the tank.)

8.2 General Policy Objective - Postmission Disposal of Space Structures

This General Policy Objective contains guidelines 6-1 through 6-4. Only guideline 6-1 is relevant to the deboost process.

8.2.1 Guideline 6-1. *Disposal for final mission orbits passing through LEO.*

This guideline specifies three (3) methods appropriate for the post-mission disposal of spacecraft that have initial perigee altitudes at or below 2000 km. These are:

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

The IRIDIUM deboost process uses the atmospheric reentry option. The original LBCS design places the SV in a final orbit that will decay within one (1) year after reaching the target orbit. In addition, the deboost process uses "manual" OA Plans to further lower the orbit, and reduce decay time. There are no drag enhancement devices used during IRIDIUM deboost.

8.3 General Policy Objective - Limiting the Risk from Debris Surviving Uncontrolled Reentry

This General Policy Objective contains one guideline: 7-1 (Limit the risk of human casualty), which is applicable to IRIDIUM deboost.

8.3.1 Guideline 7-1. *Limit the risk of human casualty*

This guideline states that, "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 m². The guideline for uncontrolled reentry provides an upper limit of 8 m² on the total casualty area of debris that impacts the Earth. An upper limit of 8 m² is derived by assuming an average risk of human casualty of 0.0001 per reentry event. However, the risk of a reentry event causing any casualties is actually lower since no correction has been made for the fact that people are usually protected inside buildings or vehicles and will therefore be shielded from reentering debris. To date, no casualties have been attributed to reentering man-made space structures."

“Assessment of On-Orbit and Terrestrial Risks from IRIDIUM Spacecraft,” published by the Johnson Space Center (April 2000), shows that IRIDIUM is compliant with this requirement.

9. DEBOOST PLAN UPDATES

Boeing will hold a quarterly internal review to update the Deboost Plan. A team including key technical and management personnel will participate to ensure the Deboost Plan remains current. All documents and procedures related to deboost will be reviewed and updated quarterly. A list of all procedures that are specific to deboost are included in “Deboost Document and Procedure List” (GEN-00008-IR). All contact lists will be updated quarterly to ensure Boeing is coordinating with the proper external agencies.

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COMMUNICATION WITH U.S. GOVERNMENT AGENCIES

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Appendix A - Data Formats A-1

1. PURPOSE

This document outlines the processes used by Iridium operations personnel to communicate/coordinate with agencies of the United States Government.

2. SCOPE

Operations personnel are often required to communicate with U.S. Government agencies, such as NASA, U.S. Space Command, Naval Space Command, and the U.S. Air Force. There are several released documents in existence that discuss the communications processes already in place. This document is a summary of those processes.

3. REFERENCES

Document Title	Document Number
Launch Notifications Procedure	12-P40583L
Request Support for Lost SV Procedure	12-P40566L
Deboost Conjunction Notification and Escalation Guide	MAN-00005-IR

4. DEFINITIONS

LCASP - Launch Collision Avoidance Support Package

OA - Orbit Analyst

OSC - Operations Support Center (Goddard Space Flight Center)

TLE - Two Line Element Set

GAM - Ground Anomaly Meeting

5. SUMMARY OF EXTERNAL CONTACTS FOR LAUNCH NOTIFICATION

“Launch Notifications Procedure” (12-P40583L) is the official procedure for performing pre-launch notifications. There are two types of external notifications required to support upcoming launches: the launch base notification, and the satellite notification.

5.1 Launch Base Notification

For Delta II Launches, no Launch Base Notification is required, as Boeing Commercial Delta handles necessary launch notifications. For launches done using foreign launch providers, the U.S. State Department requires a Launch Collision Avoidance Support Package (LCASP) to be provided. In support of this, a Boeing Orbit Analyst (OA) must provide separation vectors to populate the LCASP. Boeing must forward the completed LCASP to the State Department.

5.2 Satellite Notifications

The Boeing Orbit Analyst is responsible for distributing two (2) satellite notifications. At L-15 days, the OA sends a fax notification of the planned launch date/time. A second notification is sent at L-4 days. Further notification are delivered whenever a launch slips. Notifications are sent to the following groups¹:

¹ For Points of Contact within the specified groups, please refer to the controlling procedure or document.

- NASA Goddard
- J3, U.S. Space Command
- Chief Analyst, ICACS
- Chief Architect
- Other²

6. LOST SV SUPPORT

“Request Support for Lost SV Procedure” (12-P40566L) is the official procedure for requesting element sets from external agencies to assist operations in finding an SV that has missed one or more schedule contacts.

The official procedure requires a Boeing Orbit Analyst to contact the Operations Support Center (OSC) at Goddard Space Flight Center¹. The OSC contact may give permission to contact U.S. Space Command 1st Command and Control Squadron. If permission is given, the OA may contact the squadron commander to request element set assistance. If permission is not given for the OA to contact U.S. Space Command directly, then NASA itself will pass the request along.

7. EXTERNAL COMMUNICATIONS DURING DEBOOST OPERATIONS

7.1 Daily Coordination with U.S. Space Command

The OA Shift Lead is responsible for ensuring that Two-Line Element Sets are electronically distributed for all controlled Iridium SVs to U.S. Space Command every eight hours during deboost operations.

Every twelve hours, the OA Team is responsible for providing a set of CALIPER inputs for each deboosting SV. The format of the CALIPER input file is given in Appendix A. U.S. Space Command uses these inputs as the input to its CALIPER collision prediction tool. Also, the OA Team will electronically distribute predicted Two-Line Element Sets (See Appendix A) for each deboosting SV to predict the orbit given the burns in the OA Plan.

The OA Team will distribute Two-Line Element sets to “other” agencies every 24 hours.

7.2 Weekly Communication

The Deboost Operations Manager is responsible for distributing a Weekly Deboost Summary report, showing the SVs that are inert, in controlled deboost, or in mission/storage orbit. In addition, the OA Team will provide predicted ground traces for deboosting SVs, and predicted final orbits for deboosting SVs.

This weekly report will be distributed using the Iridium Operations Advisory (see below).

7.3 Ad-Hoc Communication

The Deboost Operations Manager is responsible for performing ad-hoc communications with representatives of external agencies. These communications are made using the “Iridium Operations Advisory” function built into the Deorbit History (Access) Database. Operations Advisories are distributed under the following conditions:

- Advance notice that a deboost is about to begin.
- An SV deviates from the on-board OA Plan.
- An SV completes the MPC to Deboost.

² “Other” represents a classified agency/agencies. Further information available on a need-to-know basis.

- The passivation sequence is sent to an SV to complete deboost, or an SV is no longer being controlled for other reasons.
- A collision avoidance action is going to be taken and an SV is going to stop maneuvering.

Operations Advisories are sent to representatives of the following U.S. Government agencies^{1,2}:

- Naval Space Command.
- J3, U.S. Space Command.
- NASA.
- 1st Command and Control Squadron, U.S. Space Command.
- U.S. Air Force Space Command.
- "Other."

7.4 Collision Avoidance Coordination

Collision Avoidance Coordination is covered in the "Deboost Conjunction Notification and Escalation Guide" (MAN-00005-IR). Collision avoidance between Boeing and U.S. Space Command is an ongoing activity during deboost operations.

U.S. Space Command performs collision predictions using the CALIPER input files generated by the Orbit Analysis Team (see section 7.1), and notifies the Deboost Operations Manager, Deputy Deboost Operations Manager, and Orbit Analysis Lead of any pending conjunction events. The collision analysis is done once per eight hour shift, so the notifications can occur up to three times a day. Notifications are initially verbal, followed by a fax or email.

The "Deboost Conjunction Notification and Escalation Guide" (MAN-00005-IR) details the collision avoidance timeline. If it is determined (via a GAM) that a collision avoidance action is required, the Deboost Operations Manager will issue an Iridium Operations Advisory (see section 7.3) to that effect.

8. COORDINATION ACTIVITIES NOT COVERED ELSEWHERE

The deboost-related documents are scoped to cover a constellation-wide decommissioning activity. However, the coordination efforts will be the same for a single-SV deorbit. Additionally, Iridium Operations Advisories will be issued for SVs that are being moved from Storage to Mission, or from Mission to Engineering Orbit.

APPENDIX A - DATA FORMATS

Table A- 1. CALIPER Input

Column								
1	2	3	4	5	6	7	8	9
123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890								
LAUNCH TIME: YYYY DDD HHMM SS.SSS LAUNCH AZIMUTH: AAA.AAA DISPERSION FILE: FFFFFFFF								

where YYYY = Launch Year (Launch times are always expressed in UTC)
 DDD = Launch Day in Year
 HH = Hour of Launch
 MM = Minute of Launch
 SS.SSS = Second of Launch
 AAA.AAA = Launch Azimuth (Degrees) (Can be 0.000.)
 FFFFFFFF = Name of Section of Dispersions File (Not currently used).

This will be followed by as many sets of three lines as needed to fully specify the ephemeris for the launch. The three lines are as follows:

Column								
1	2	3	4	5	6	7	8	9
123456789012345678901234567890123456789012345678901234567890123456789012345678901234567890								
TTTTT.TTT ±EEEEEE.EEE ±FFFFFF.FFF ±GGGGGG.GGG								
. ±EDE.DEDEDE ±FDF.DFDFDF ±GDG.DGDGDG								
±.EDEDEDED ±.FDDFDDFDD ±.GDDGDDGDD								

where TTTTT.TTT = Mission Elapsed Time (MET) (Seconds)
 EEEEE.EEE = E Component of Position (Kilometers)
 FFFFFFF.FFF = F Component of Position (Kilometers)
 GGGGG.GGG = G Component of Position (Kilometers)
 EDE.DEDEDE = E Component of Velocity (Kilometers per Second)
 FDF.DFDFDF = F Component of Velocity (Kilometers per Second)
 GDG.DGDGDG = G Component of Velocity (Kilometers per Second)
 .EDEDEDED = E Component of Acceleration (Kilometers per Second²)
 .FDDFDDFDD = F Component of Acceleration (Kilometers per Second²)
 .GDDGDDGDD = G Component of Acceleration (Kilometers per Second²)

Format for Predicted Two-Line Element Sets

The Orbit Analysis Team will electronically distribute Two-Line Element sets for each deboosting SV in the following format:

- SVID/Object #
- TLE (start)
- TLE + 1 burn (Predicted)
- TLE + 2 burns (Predicted)
- TLE + 3 burns (Predicted)
- ...
- TLE + n burns (Predicted)

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CONSTELLATION DEBOOST CHECKLIST

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**DEBOOST CONJUNCTION
NOTIFICATION AND ESCALATION GUIDE**

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1. PURPOSE

This document defines the manner in which Operations, Engineering, Management and external agencies are to be contacted in the event that a conjunction is predicted between a deboosting IRIDIUM satellite and another space object.

2. SCOPE

This document applies to Boeing personnel responsible for handling the escalation/notification part of the Collision Avoidance Process. This process encompasses conjunctions predicted for three classes of space objects:

- Class 1: Manned (Shuttle, ISS, Mir).
- Class 2: Active Unmanned (Live Payloads).
- Class 3: Debris (Rocket Bodies, Dead Satellites).

3. REFERENCES

None

4. DEFINITIONS/ACRONYMS

Collision Avoidance (COLA)- Actions taken to reduce the possibility of a conjunction between two space objects, specifically the suspension of one or more planned burns between 12 and 36 hours prior to a conjunction event. This will provide an in-track separation between the SV and the conjuncting space object.

Conjunction - The intersection of exclusion zones surrounding two space objects.

Conjunction Prediction - Predicted intersection of a Boeing-operated SV with another space object, based on US Space Command's General Perturbation (GP) database.

Conjunction Event - A conjunction event is a conjunction prediction which meets ALL of the following criteria:

1. Meets the guidelines for the class of object for which an action (collision avoidance) would be performed.
2. Has been verified against US Space Command's Special Perturbation (SP) database using the most accurate available prediction of the SV.
3. Has been compared against intermediate post-burn element sets (provided by Boeing every 24 hours and spanning 36 hours) to identify a working range for the collision avoidance action.

Exclusion Zone - A volume surrounding a space object within which another space object may not enter.

Notification - Passing along event information to those with a need to know.

Maneuver Guidelines - A previously agreed-upon set of conditions for identifying conjunction predictions that need to be evaluated further, understood by both US Space Command and Boeing.

Ground Anomaly Meeting (GAM) - Meeting with key management and technical personnel where permission is granted to perform a Collision Avoidance Maneuver.

5. CONJUNCTION PREDICTION AND CONJUNCTION EVENT

5.1 Conjunction Event Notification from US Space Command

US Space Command will notify the Deboost Operations Manager, and Orbit Analysis Lead of a conjunction event. The initial notification will be verbal, followed by a hardcopy notification (fax or email TBD).

5.2 Format of Conjunction Event Notification from US Space Command

This notification will be in the format of the OCM. It will include, but not be limited to, the following information: IRIDIUM SVID, Date/Time of Conjunction, Identifier for Conjoining Object, Vector of Conjoining Object, and Missed Distance.

5.3 Conjunction Prediction Timeline

US Space Command will generate conjunction predictions based on the burn profile provided by Boeing twice a day spanning 96 hours. The burn profile will be compared against the GP database. The burn profile and conjunction predictions are for use by US Space Command only. No notification will be sent for conjunction predictions.

5.4 Conjunction Event Timeline

US Space Command will use the conjunction predictions as described in Section 5.3 to select space objects to be processed against the SP database, based on previously agreed-upon maneuver guidelines. For conjunction predictions that fall in the next 36 hours, the intermediate post-burn element sets will be compared against the SP database in order to identify a range of vectors for which the predicted conjunction disappears. This prediction has now met the definition of a conjunction event. US Space Command will notify the Deboost Operations Manager, Deputy Deboost Operations Manager and the Orbit Analysis Lead Engineer of the conjunction event, as defined in Section 5.1.

This process is expected to take a maximum of 4 hours. The process will be performed once per 8 hour shift. This implies a maximum latency of 12 hours. The notification should arrive no later than 24 hours prior to the conjunction event.

5.5 Collision Avoidance Timeline

The collision avoidance timeline commences no later than 24 hours prior to a conjunction event. As defined above, collision avoidance is the act of suspending a planned maneuver in order to achieve an in-track separation from the conjoining object and avoid a collision event.

This is achieved by interrupting a single burn in the range identified by US Space Command. At most, 2 orbit revolutions, or 3.3 hours, are required to initiate collision avoidance (assuming two command opportunities are needed).

Approval for performing collision avoidance is through a GAM, which can be completed in an additional 20 minutes.

The collision avoidance action is to be completed no later than 20 hours prior to the conjunction event.

6. RESPONSE TO CONJUNCTION EVENT

6.1 Conjunction Event GAM

6.1.1 GAM List

GAM escalation to Boeing personnel will be made via pager to the predefined group of people. The Phase Manager will send a page to the following list of people:

- Orbit Analysis Lead.
- Orbit Analysis Duty Pager.
- Deboost Operations Manager.
- Deputy Deboost Operations Manager.
- Real Time Operations Duty Pager.
- Space Network Lead.
- Space Network Duty Pager.
- Space Network Propulsion Engineer.
- Mission Operations Manager.
- Chief Engineer.
- Chief Architect.
- Deputy Program Manager.
- Program Manager.

6.1.2 GAM Page Format

The GAM page will be in the following format:

COLA GAM

ELEMENT: SVxxx

CLASS: x

CONJUNCTION EVENT @ date time

GAM LEADER:

GAM TIME:

CALL:

6.2 Collision Avoidance Decision

6.2.1 Collision Avoidance Decision Authority

If necessary, the decision to perform collision avoidance (COLA) activities will be the result of the GAM. During the GAM, verbal approval will be given to perform collision avoidance activities. This verbal approval will be sufficient to begin COLA activities as soon as necessary. A Change Request will be submitted and approved at the

Operations Configuration Control Board (OCCB) to document the approval for COLA activities granted in the GAM.

Only consensus among the following people will be considered as verbal approval to begin COLA activities:

Primary	Alternate
Program Manager	Deputy Program Manager
Chief Engineer	Chief Architect
Deboost Operations Manager	Deputy Deboost Operations Manager

6.2.2 Collision Avoidance Decision Criteria

Collision avoidance decisions will depend upon the class of space object with which the conjunction event will occur. From a workload perspective, the SNOC cannot execute more than three Class 2 and Class 3 COLA events in 1 week without affecting normal operations. All efforts will be made to avoid conjunctions with Class 1 objects.

6.2.3 Collision Avoidance Decision Notification to External Agencies

External agencies will be notified via email distribution after a GAM decision to proceed with a collision avoidance action. The Orbit Analysis Shop will distribute new Two Line Element (TLE) sets and CALIPER files as soon as possible after the collision avoidance action has been successfully initiated.

The format of the advisory message will include the following information:

- Advisory Number: database generated.
- Date/Time: database generated.
- Advisory Type: COLA Action.
- SVID.
- Object Number: database generated based on SVID.
- Deboost Group: database generated based on SVID.
- Sent by: from database pulldown menu.

Sample text:

“Maneuvers for SVxxx will be suspended between <Date/Time GMT> and <Date/Time GMT> in order to mitigate a potential conjunction with <Object Name and Number>. The predicted conjunction time is <Date/Time GMT>.

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Deboost Passivation Sequence

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1. SUMMARY AND PURPOSE

This document outlines the SV configuration required to passivate the SV at the end of a planned deorbit. The concept is to place the SV in a condition that has no stored remaining energy. Since this is considered to be a "poison pill" for the SV, action will have to be taken by ground control to load and activate the SV for a planned deorbit. The SV will not be changed to autonomously execute the "passivation" maneuver so it cannot be executed accidentally by the SV, since its execution is the guaranteed death of the SV. An unplanned deorbit, therefore, either started erroneously or due to loss of contact with the ground will not result in a passivated SV unless contact can be reestablished with the deorbiting SV.

2. REFERENCES

None

3. TERMS AND ACRONYMS

BOM	Bus Operations Mode
Cmd	Command
Ctr	Counter
E&A	Engineering & Analysis
LBCS	Lockheed Bus Control Software
PIV	Propellant Isolation Valve
SV	Space Vehicle
SVARC	Space Vehicle And Routing Computer

4. SEQUENCE DEFINITION

4.1 Passivation Invoke Sequence (A.K.A. The Poison Pill)

Cmd #	Relative Time Tag (sec)	Function	Command (Parameters)	Cmd Ctr
1	1.0	LBCS BOM Enable.	LBC_BOMXTNEN (XTNENBLST=1 [BOMXTNENBL])	Non-Zero
2	2.0	Turn off LBCS Fault Management.	LBC_BXFLTMGR (BX_MDFLTMGR=25 [FLTMGR], BX_LFMRQ=0 [OFF])	Non-Zero
3	3.0	Move the solar arrays to azimuth deploy (zero azimuth angle).	LBC_BXSACTRL (BX_MDSACTL=6 [SACTRL], BX_SACTLRQ=3 [AZ_DEPLOY])	Non-Zero
4	545.0	Hold the solar arrays in position.	LBC_BXSACTRL (BX_MDSACTL=6 [SACTRL], BX_SACTLRQ=4 [HOLD])	Non-Zero
5	546.0	Move the -Y elevation 90 degrees off from the +Y	LBC_ORSAME (DURATN=265.42,	Non-Zero

Cmd #	Relative Time Tag (sec)	Function	Command (Parameters)	Cmd Ctr
		array).	DIRCNT=4, SADAPP=26)	
6	812.0	Set the LBCS software status for the PIV to closed (PIV actually stays open).	LBC_SETHWST (HWSTAT_INDEX=37 [PIV_STS], HW_STATUS=11 [HW_CLOS_NFAI])	Non-Zero
7	813.0	Change the Attitude Control Mode to flush lines.	LBC_BXATTCTL (BX_MDATTCTL =3 [ATTCTL], BX_ATTCTLRQ=1 [FLUSH_LINES])	Non-Zero
8	814.0	LBCS BOM Disable.	LBC_BOMXTNEN (XTNENBLST=0 [BOMXTNDSBL])	Non-Zero
9	815.0	Turn off battery charge control on SVARC1.	ARD_POKMEM (ADDR_POK=LBC_BATCTLCI Address, POKEDATA=0x10000000, CPUID=1 [SVARC1])	Non-Zero
10	816.0	Turn off battery charge control on SVARC2.	ARD_POKMEM (ADDR_POK=LBC_BATCTLCI Address, POKEDATA=0x10000000, CPUID=6 [SVARC2])	Non-Zero

4.2 Address for ARD_POKMEM commands based on SVARC executable image.

SVARC Software Load	Address of the LBC_BATCTLCI
FED	0x00405BA4
FGT / FG TG	0x00407644
FGU	TBD

Note: Use the appropriate address for the LBC_BATCTLCI for the software load on the SVARC that is to be poked

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REV	DESCRIPTION	DATE	APPROVED
V1	Level 3 Initial Release	03/14/01	

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1. PURPOSE

This document provides a list of all the unique documents and procedures that pertain to or are used for performing the deboost of the Iridium constellation. The documents and procedures in the list will be reviewed as part of the Boeing quarterly deboost review.

2. SCOPE

This document applies to the deboost and decommissioning of the full IRIDIUM constellation, and although parts of the document are applicable to a "single SV" deboost, this document is not intended to specifically cover that case. This list of documents and procedures include only those that are unique or pertain directly to the Deboost Plan. Many documents and procedures are used for other mission phases will also be used for deboost. The assumption is that these documents and procedures will be maintained as part the other normal O&M processes and that only the deboost unique items need review.

3. DOCUMENTS AND PROCEDURES UNIQUE TO DEBOOST

Table 1 Documents and Procedures Unique to Deboost

Doc. # and Revision	Document	Summary
12-P40970L Rev X1	FGT to FGT Planned Switch Re-Orbit Checklist	Contains steps for Planned SVARC switch recovery during Deboost for SVs with FGT PLSW
12-P40971L Rev X1	Deboost Software Upload and Activation Procedure	Procedure for uploading Deboost S/W products
12-P41412L Rev X1	Orbit Analysis Deboost Checklist	Contains steps that OA needs to perform for every SV prior to the start of deboost all the way to passivation
PRO-00002-IR V1	Constellation Deboost Checklist	The "MASTER" Deboost checklist, from which other Deboost checklists and procedures are called.
12-P41123L Rev X1	Mission Planning Tools: Execute Visibility Inspector Tool	MP procedure
12-P41124L Rev X1	Quickplan Tools: Changing AOS/LOS Times in Quickplan	MP Procedure
12-P41125L Rev X1	Mission Planning Tools: Producing a New PIL File from a new schedule	MP Procedure
68-P40753L Rev X1	Deboost Controller (DC) and Phase Manager (PM) Performance Objectives	Deboos- related training material
68-P40774L Rev X1	Lesson 3005: RTO Re-orbit Topics	Deboost-related training material
68-P40775L Rev X1	Lesson 3001: Deboost Operations Overview	Deboost-related training material
68-P40776L Rev X1	Lesson 3002: Deboost Operations	Deboost-related training material
MAN-00005-IR V1	Deboost Conjunction Notification and Escalation Guide	Contains collision avoidance process

Doc. # and Revision	Document	Summary
PLA-00001-IR V1	IRIDIUM Constellation Re-Orbit Plan (Deboost Plan)	Highlights overall Deboost process
99-P41429L Rev X5	Deboost Rehearsal Plan	Deboost-related training material
99-P41435L Rev X1	IRIDIUM Constellation Deboost Risk Management Plan	Identifies risks associated with Constellation Deboost and possible mitigation strategies
GEN-00006-IR V1	IRIDIUM Space Vehicle Deorbit Passivation Sequence	Details the SV Passivation process
GEN-00007-IR V1-	IRIDIUM SV Lifecycle Configuration Control Guide	Contains Software that must be changed when transitioning between SV Lifecycle states
TBD	Interrupt Burn Procedure	Contains steps necessary to interrupt an SV burn plan
TBD	Mission Planning Contingency Planning Process	MP procedure
TBD	Generic Deboost Procedure	Contains steps necessary to transition a nominal (healthy) SV into the Deorbit Mission Phase
TBD	SVARC2 Deboost Procedure	Contains steps necessary to transition a SVARC2 SV into the Deorbit Mission Phase
TBD	Single SVARC Deboost Procedure	Contains steps necessary to transition a single SVARC SV into the Deorbit Mission Phase
TBD	Failed TGA Good MWA Deboost Procedure	Contains steps necessary to transition an SV with Failed TGA/ Good MWA into the Deorbit Mission Phase
TBD	No RF Procedure for Non-Mission SV	This procedure details the steps that are to be taken if a Line-of-Sight only SV experiences a No-RF.
In-work	FGT to FGT Unplanned Switch Re-Orbit Checklist	Details the steps necessary to recover an SV in Deorbit Mission Phase from an unplanned SVARC switchover on FGT PLSW
In-work	Lesson 3004: Constellation K-Band Operations for Multiple Deorbit Phase SVs	Deboost-related training material
Needs to be developed	FGU to FGU Planned Switch Re-Orbit Checklist	Contains steps for Planned SVARC switch recovery during Deboost for SVs with FGU PLSW
Needs to be developed	FGU to FGU Unplanned Switch Re-Orbit Checklist	Details the steps necessary to recover an SV in Deorbit Mission Phase from an unplanned SVARC switchover on FGU PLSW

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IRIDIUM®
SV LIFECYCLE CONFIGURATION CONTROL GUIDE

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1. SUMMARY AND PURPOSE

This document outlines the software configuration changes required for an SV as it progresses through its lifecycle from launch to mission orbit, through deorbit. Certain configuration changes are required for an SV as it progresses through the different phases of its lifecycle. These different phases of its lifecycle are described in the `lbsc_config_file_sv_classes.txt` file (see CMVC release 98-P80140W101), which is used by the BOM builders, Space Systems and Operations to configure the SV in the different parts of its lifecycle.

This document breaks the SV lifecycle into different classes. The `lbsc_config_file_sv_classes.txt` file defines the class for which an SV is a member and is used in conjunction with the LBCS version specific documents, such as `lbsc_r2.8.35_config_usage.txt`, which describes the LBCS configuration files that are to be used with a particular class of SVs.

This document attempts to go one step further and describes additional SV configuration changes required at different stages in the lifecycle to best guarantee that the SV completes each stage of the mission successfully. This document serves as a guideline for configuring a "standard" SV. The state of health of an actual SV must be taken into account when an SV is reconfigured for a mission phase transition. Additional and/or alternate reconfiguration changes may be required for an SV that has unique hardware issues.

2. TERMS AND ACRONYMS

ATCT	Attitude Control
ATPR	Attitude Profile
BATC	Battery Charge Control
BOM	Bill of Materials
Config File	LBCS Configuration File
CF	Config File
CI	Configurable Item
CMVC	Configuration Management Version Control
HB	Heavy Battery
KBA	K-Band Antenna
LB	Light Battery
LBCS	Lockheed Bus Control Software
LEOP	Launch & Early Operations Phase
LV	Launch Vehicle
MP	Mission Phase
MMA	Main Mission Antenna
NB	Narrow Band
PA	Post Ascent
PL	Post LEOP
RXL	Right Cross Link

SNOC	Satellite Network Operations Center
SV	Space Vehicle
SVM	Space Vehicle Management
TRF	Telemetry Report Format
ULT	Ultra Low Thruster

3. SV LIFECYCLE PHASES

The SV lifecycle phases and the software reconfiguration required to support the given phases are presented in this section.

3.1 Launch Configuration

- CF02_ATCT_Config.bin.
- CF04_ATPR_Drift_Config.bin.
- CF05_BATC_Config.bin (Heavy Battery, Wide eclipse Band, No Voltage for undercharge voting).
- KBA CI's with RXL registered forward.
- Launch LBCS CI's, Launch SV Ephemeris, Pre-Jamset Time Sync Message and LEOP battery control parameters.
- SVM CI's for MMA heater settings at qualification values (original Phase0 values).
- ROM CI's routing to Feederlink 1.
- LEOP, Ascent and Mission Transition TRFs.
- LEOP Safemode Sequence.
- LEOP Normal Ops Sequence.
- LEOP Deployment and LEOP Sequence.

3.2 Ascent Configuration

- CF02_ATCT_UL_T_PL_Config.bin (Ultra Low Thruster, Post LEOP gains).
- CF04_ATPR_Drift_Config.bin.
- CF05_BATC_HB_NB_No_Volt_Config.bin (Heavy Battery, Narrow eclipse Band, No Voltage for undercharge voting).
- KBA CI's with RXL registered forward on the initial Ascent MP (from LV parking orbit to Storage or Mission).
- KBA CI's with RXL registered rearward on subsequent entries to the Ascent MP.
- Ascent LBCS CI's, Post-Jamset Time Sync Message and ascent battery control parameters.
- ROM CI's routing to Feederlink 2.
- SVM CI's for MMA heater settings at qualification values (original Phase0 values).
- Ascent and Mission Transition TRFs.

- Ascent/Storage/Drifter Storage Safemode Sequence.
- Ascent/Storage/Drifter Normal Ops Sequence.
- No-Op Deployment and LEOP Sequences.
- Poke Coldstart for Phase-F SVARC (not needed for FGU and later builds) software configuration (This is required for Ascent to prevent an OA replan after a quickstart without the SNOC knowledge of the replan).

3.3 Drifter Configuration

- CF02_ATCT_UL_T_PL_Config.bin (Ultra Low Thruster, Post LEOP gains).
- CF04_ATPR_Drift_Config.bin.
- CF05_BATC_HB_NB_No_Volt_Config.bin (Heavy Battery, Narrow eclipse Band, No Voltage for undercharge voting).
- Drifter LBCS CI's, Drifter SV Ephemeris, Post-Jamset Time Sync Message and storage battery control parameters.
- ROM CI's routing to Feederlink 2.
- SVM CI's for MMA heater settings at qualification values (original Phase0 values).
- Ascent, Mission Transition and Mission TRFs.
- Ascent/Storage/Drifter Storage Safemode Sequence.
- Ascent/Storage/Drifter Normal Ops Sequence.
- No-Op Deployment and LEOP Sequences.

3.4 Storage Configuration

- CF02_ATCT_UL_T_PL_Config.bin (Ultra Low Thruster, Post LEOP gains).
- CF04_ATPR_Config.bin (Mission Standard Configuration).
- CF05_BATC_HB_NB_No_Volt_Config.bin (Heavy Battery, Narrow eclipse Band, No Voltage for undercharge voting).
- Storage LBCS CI's, Storage SV Ephemeris, Post-Jamset Time Sync Message and storage battery control parameters.
- ROM CI's routing to Feederlink 2.
- SVM CI's for MMA heater settings at qualification values (original Phase 0 values).
- Ascent, Mission Transition and Mission TRFs.
- Ascent/Storage/Drifter Safemode Sequence.
- Ascent/Storage/Drifter Normal Ops Sequence.
- No-Op Deployment and LEOP Sequences.

3.5 Mission Configuration

- CF02_ATCT_UL_T_PA_Config.bin (Ultra Low Thruster, Post Ascent gains).

- CF04_ATPR_Config.bin (Mission Standard Configuration).
- CF05_BATC_HB_Narrow_Band_Config.bin or CF05_BATC_LB_Narrow_Band_Config.bin (Heavy or Light Battery, Narrow eclipse Band).
- Mission LBCS CI's, Mission SV Ephemeris, Post-Jamset Time Sync Message and mission battery control parameters.
- ROM CI's routing to Aft Crosslink.
- Mission SVM CI's for MMA heater settings.
- Mission Transition and Mission TRFs.
- Mission Safemode Sequence.
- Mission Normal Ops Sequence.
- No-Op Deployment and LEOP Sequences.

3.6 Engineering Orbit Configuration

- CF02_ATCT_ULT_PL_Config.bin or CF02_ATCT_ULT_PA_Config.bin.
- CF04_ATPR_Config.bin (Mission Standard Configuration).
- CF05_BATC_HB_NB_No_Volt_Config.bin or CF05_BATC_LB_NB_No_Volt_Config.bin (Heavy or Light Battery, Narrow eclipse Band, No Voltage for undercharge voting).
- Engineering Orbit LBCS CI's, Engineering Orbit SV Ephemeris, Post-Jamset Time Sync Message and storage orbit battery control parameters.
- ROM CI's routing to Feederlink 2.
- SVM CI's for MMA heater settings at qualification values (original Phase 0 values).
- Ascent, Mission Transition and Mission TRFs.
- Ascent/Storage/Drifter Safemode Sequence.
- Ascent/Storage/Drifter Normal Ops Sequence.
- No-Op Deployment and LEOP Sequences.

3.7 Deorbit (Planned) Configuration

- CF02_ATCT_Config.bin.
- CF04_ATPR_Config.bin or CF04_ATPR_Drift_Config.bin.
- CF05_BATC_HB_NB_No_Volt_Config.bin or CF05_BATC_LB_NB_No_Volt_Config.bin (Heavy or Light Battery, Narrow eclipse Band, No Voltage for undercharge voting).
- FLS CI's Feederlink tap rails frozen to "average" values.

- Mission or Storage LBCS CI's with modified deorbit delay times:
 - Mission: Phase 1 delay 86400 (may be modified to shorter value as needed by Ops).
Phase 2 delay 0 (RAM upload required to a non-zero value for the restart of an interrupted deorbit).
 - Non-Mission: Phase 1 delay 14400 (may be modified to shorter value as needed by Ops).
Phase 2 delay 0 (may be modified to shorter value as needed by Ops).
- Post-Jamset Time Sync Message and ascent battery control parameters.
- KBA CI's maximum Feederlink azimuth slew rates.
- ROM CI's routing to Feederlink 2.
- SVM CI's for MMA heater settings at qualification (original Phase0 values) or Safemode values.
- Command heaters to Safemode values.
- Ascent, Mission Transition and Mission TRFs.
- Special Deorbit Safemode Sequence (modified version of the Ascent/Storage/Drifter Safemode Sequence).
- Special Deorbit Normal Ops Sequence (modified version of the Ascent/Storage/Drifter Safemode).
- No-Op Deployment and LEOP Sequences.
- Deboost Passivation Invoke Sequence

4. LIFECYCLE DEPENDENT CI SETTINGS

The SV lifecycle dependent CI settings required to support the given phases are presented in this section.

4.1 FLS Lifecycle Dependent CI Settings

FLS CI Values for Non-Deorbit Configuration (Configuration Numbers 1-6)

FLS_EQCNST FL_EQ_MD	7
FLS_EQCNST FL_EQ_CA	193
FLS_EQCNST FL_EQ_EI	0
FLS_EQCNST FL_EQ_EQ	0
FLS_EQCNST FL_EQ_LI	0
FLS_EQCNST FL_EQ_LQ	0

FLS CI Values for Deorbit Configuration (Configuration Number 7)

FLS_EQCNST FL_EQ_MD	3
FLS_EQCNST FL_EQ_CA	90
FLS_EQCNST FL_EQ_EI	-2
FLS_EQCNST FL_EQ_EQ	-2
FLS_EQCNST FL_EQ_LI	-15
FLS_EQCNST FL_EQ_LQ	0

4.2 KBA Lifecycle Dependent CI Settings

KBA CI Values for Non-Deorbit Configuration (Configuration Numbers 1-6)

KBA_MORULE3 KB_MORUL31	6
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KBA CI Values for Deorbit Configuration (Configuration Number 7)

KBA_MORULE3 KB_MORUL31	19
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EXHIBIT F

CALEA and National Security Compliance: Iridium Satellite will diligently work to address government law enforcement and national security concerns. It hopes to secure an agreement quickly by relying, at least in part, on the review conducted for the original IRIDIUM system.

Radio Astronomy Issues: Prior to initiating service, Iridium LLC and Motorola completed a series of agreements with various radio astronomy groups in the United States regarding the protection of radio astronomy frequencies as required by Section 25.213 of the Commission's Rules and by the space segment license.¹ Iridium Satellite will commence discussions, as soon as practicable, with these various groups to assign these agreements to the proposed new licensee.

¹ Iridium Satellite intends to commence similar discussions with radio astronomy groups outside the U.S.

EXHIBIT G

SECTION 25.116 EXEMPTION AND AMS(R)S ASSUMPTION

Section 25.116 Exemption: Iridium Satellite, LLC (“Iridium Satellite”) requests an exemption from the applicable cut-off date pursuant to Section 25.116(c)(2) in order to assume Iridium LLC’s pending application to construct, launch and operate a so-called 2 GHz Mobile Satellite Services (“MSS”) system. *See* 47 C.F.R. § 25.116(c)(2). On September 26, 1997, Iridium LLC applied for authority to launch and operate the MACROCELL Non-Geostationary Mobile Satellite System in the 2 GHz band. *See* FCC File No. 187-SAT-P/LA-97(96), IBS File No. SAT-LOA-1997-0926-00147. This application was filed following the release of a Commission decision allocating a portion of the 2 GHz band for MSS and in response to public notices announcing a cut-off date for the filing of 2 GHz MSS license applications in an initial processing round.¹ On November 3, 2000, Iridium LLC filed an amendment to its application in accordance with the recently released Report and Order establishing service rules for the new 2 GHz Mobile Satellite Service.²

Iridium Satellite submits that an exemption under Section 25.116 of the Rules is clearly in the public interest. The Commission generally considers two factors when granting an exemption to cut-off rules: (1) whether the proposed transaction had a legitimate business purpose and (2) whether the change in ownership otherwise would serve the public interest.

¹ *Amendment of Section 2.106 of the Commission’s Rules to Allocate Spectrum at 2 GHz for Use by the Mobile-Satellite Service*, ET Docket No. 95-18, First Report and Order and Further Notice of Proposed Rule Making, 12 FCC Rcd 7388 (1997) (*2 GHz MSS Allocation Order*).

² *See Establishment of Policies and Service Rules in the Mobile Satellite Service in the 2 GHz Band*, IB Docket No. 99-81, FCC 00-302, released August 25, 2000, 15 FCC Rcd 16127 (2000).

See, e.g., Loral Space & Communications, Ltd., 13 FCC Rcd 4592, 4599 (1998); *Air Signal International, Inc.*, 81 F.C.C.2d 472 (1980).

When the request to assume a pending application is incidental to a larger multifaceted transaction, the Commission has found that such assumption (via amendment) is for legitimate business purposes and has granted exemptions to any cut-off dates under 25.116(c)(2), or similar Commission rules. *See, e.g., Constellation Communications, Inc.*, 11 FCC Rcd 18,502 (1996) (waiving Section 25.116 where ownership changes resulted in part from larger corporate transactions involving acquisition of other lines of business and in part to strengthen finances); *Air Signal International, Inc.*, 81 F.C.C.2d 472, 475 (1980) (waiving Part 22 cut-off rules when amendment to pending application reflecting change in ownership as a result of the merger of applicant's parent company was incidental to larger transaction, and no indication existed that major purpose for the merger was to obtain pending applications). Iridium Satellite's request to assume Iridium LLC's pending 2 GHz application is incidental to the overall acquisition of the IRIDIUM System out of bankruptcy and thus is clearly undertaken for an independent, legitimate business purpose. Iridium Satellite does not principally seek to acquire Iridium assets so that it may assume control of Iridium LLC's pending 2 GHz application; nor is its request for a waiver from processing a new processing round an attempt to gain a "competitive []advantage" over the other applicants in the current 2 GHz processing round. *See AT&T & Ford Aerospace Satellite Services Corp.*, 2 FCC Rcd 4431, ¶ 16 (1987). The Commission recently made a similar determination for a different 2 GHz MSS applicant when it approved a transfer of control of ICO

Services Limited ("ICO") to permit ICO to emerge from bankruptcy. *See ICO-Teledesic Global Limited*, DA 01-6 (Int'l Bur. Jan. 9, 2000).

The proposed change in ownership of the application is also in the public interest. Iridium Satellite's ability to construct and launch these so-called second generation satellites will provide greater choice and increased competition for U.S. government, industrial, and individual customers. Further, the Commission has long recognized the public interest value in applicants strengthening their financial resources and capacities to meet the heavy and costly burdens associated with constructing, launching and operating satellite systems. *See, e.g., Satellite CD Radio, Inc.*, 12 FCC Rcd 8359, 8364 (1998) (granting exemption from cut-off date since any change in ownership would strengthen applicant's financial resources and "increase the likelihood that the . . . service would promptly be made available to the public."); *Constellation Communications, Inc.*, 11 FCC Rcd 18502, 18514 (1996) (justifying exemption when change in ownership was "intended to aid in securing financial backing sufficient to facilitate prompt implementation of a competitive service."); *STARSYS Global Positioning Inc.*, 11 FCC Rcd 1237, 1238 (1995) (granting exemption where change would help to secure "financial backing sufficient to facilitate prompt implementation of competitive NVNG MSS system."). Here, these benefits are even more pronounced. Iridium LLC is currently in bankruptcy and, without the investment of Iridium Satellite, would clearly have no capability to construct and launch a 2 GHz MSS system.

Iridium Satellite respectfully requests that the Commission grant, pursuant to Section 25.116(c)(2) of its Rules, an exemption from the 2 GHz MSS cut-off date to allow

Iridium Satellite to assume Iridium LLC's pending application. Iridium Satellite also asks that the Request for Waiver of Section 63.19(a) of the Rules Regarding Discontinuance of Iridium Services, filed on March 7, 2000 by Iridium U.S., L.P. for itself and on behalf of all of its resellers, be dismissed as moot contemporaneously with grant of the authorizations sought in these applications by Iridium Satellite and its related companies.

Pending AMS(R)S Application: In December 1996, Motorola Satellite Communications, Inc. ("Motorola"), filed an application seeking authority to provide Aeronautical Mobile-Satellite Route Service ("AMS(R)S") over the IRIDIUM System. This application remains pending before the Commission. As part of its overall acquisition of IRIDIUM System assets, Iridium Satellite hereby requests approval to assume this pending application consistent with the requirements of 47 C.F.R. § 25.116(b)(3). More specifically, Iridium Satellite requests that the Commission accept a minor amendment to the pending Motorola AMS(R)S application to reflect the proposed change in ownership without triggering a separate Public Notice requirement. Additionally, Iridium Satellite requests the contemporaneous grant of the AMS(R)S application with the other applications filed herewith. AMS(R)S is an important part of Iridium Satellite's wholesale business plan to maintain the service and fully utilize the capabilities of the IRIDIUM System. In addition, as documented by Motorola in its pending application, AMS(R)S is an invaluable service to the aviation industry.