2 CHAPTER 2

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GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

30 SW/SEY - 30th Space Wing, Flight Analysis

45 LG - 45th Logistics Group

45 and 30 MDG - 45th and 30th Medical Groups

45 and 30 OG/CC - 45th and 30th Operations Groups, Operations Group Commander

45 and 30 OG - 45th and 30th Operations Group

45 and 30 RANS - 45th and 30th Range Squadron

45 and 30 SPTG - 45th and 30th Support Group

45 and 30 SW/SE - 45th and 30th Space Wing, Offices of the Chiefs of Safety

45 and 30 SW/SEO - 45th Space Wing, Mission Flight Control and Analysis and 30th Space Wing, Mission Flight Control

45 SW/SEOE - 45th Space Wing, Expendable Launch Vehicle Operations Support and Analysis

45 SW/SEOO - 45th Space Wing, Mission Flight Control

45 SW/SEOS - 45th Space Wing, Space Transportation System Operations Support and Analysis

45 and 30 SW/XP - 45th and 30th Space Wing, Plans Office

A - reference area

Accepted risk - a residual hazard that has been accepted by the Range Commander

Acs - cross-sectional area

AFI - Air Force Instruction

AFR - Air Force Regulation

AFSPC - Air Force Space Command

ANSI - American National Standards Institute

A_c - area of potential casualty

AGL - above ground level

Ap - area of population center

ASCII - American Standard for Information Interchange

beta - ballistic coefficient (W/C_dA)

cal - calorie, calories

Casualty Area - area about a hypothetical impact point of a fragment in which a defined injury to persons may occur

CCAS - Cape Canaveral Air Station

CCC - Central Computer Complex

CCP - Committed Coverage Plan

C_d - coefficient of drag

CEP - circular error probability

C_L - coefficient of lift

Command Destruct - the process whereby a command is issued from a ground station or center that, when executed by the flight system, causes the launch vehicle to destroy itself

crossrange direction - measured along the Y axis of the X, Y, Z coordinate system. Left crossrange is measured in the direction of the negative Y axis and right crossrange is measured in the direction of the positive Y axis

CVFA - continuous variable flight azimuth

deg - degree

DEP - Directed Energy Plan

deviation - a term used when a noncompliance is known to exist prior to hardware production or an operational noncompliance is known to exist prior to operations at CCAS or Vandenberg Air Force Base

dispersion impact area - an area surrounding an approved impact point; the extent and configuration of the area is based on the vehicle or stage dispersion characteristics

DoDD - Department of Defense Directive

downrange direction - measured in the direction of the positive X axis of the X, Y, Z coordinate system

drag impact points - debris impact points corrected for atmospheric drag

EFG - Geocentric Non-inertial Cartesian Coordinate system; also called Earth Centered Rotational (ECR)

E_c - casualty expectancy, expectation of casualty

GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

ER - Eastern Range

ERR - Eastern Range Regulation

FAA - Federal Aviation Administration

FFDP - Final Flight Data Package

FFPA - Final Flight Plan Approval

flight azimuth - the instantaneous angular direction of the flight trajectory of a launch vehicle measured in degrees from true North

FMECA - Failure Modes and Criticality Effects Analysis

FPA - Flight Plan Approval

FTS - Flight Termination System

ft - foot, feet

ft^2 - square feet, an area

FTS - Flight Termination System

h - hour, hours

hazard, hazardous - equipment, systems, events, and situations with an existing or potential condition that may result in a mishap

hazard analysis - the analysis of systems to determine potential hazards and recommended actions to eliminate or control the hazards

head winds - winds blowing from the reference launch azimuth.

IIP - instantaneous impact point

impact dispersion area - an area surrounding an approved impact point; the extent and configuration of the area is based on the launch vehicle and/or payload dispersion

INSRP - Interagency Nuclear Safety Review Panel

IRIG - Inter-Range Instrumentation Group

ISP - Intended Support Plan

jettisoned body - vehicle components separated at planned event times. Examples of components include stages, fairings, thrust termination ports, solid rocket motors, and associated hardware

KMR - Kwajalein Missile Range

Laser Class (1-4) - laser categories assigned in ANSI Z136.1; Class 4 being the most dangerous

L-Time (L-X) - the absolute time prior to the scheduled launch time. L-Time may be measured in seconds, minutes, hours, and days and includes all scheduled countdown holds. L-Time will always be equal or greater than T-Time.

launch area - the facility, in this case CCAS and KSC or Vandenberg Air Force Base, where launch vehicles and payloads are launched; includes any supporting sites on the Eastern and Western Ranges; also known as launch head

launch azimuth - the horizontal angular direction initially taken by a launch vehicle at lift-off; measured clockwise in degrees from true North

launch site - the specific geographical location from which a launch takes place

launch vehicle - a vehicle that carries and/or delivers a payload to a desired location; this is a generic term that applies to all vehicles that may be launched from the Eastern and Western Ranges; includes, but is not limited to airplanes; all types of space launch vehicles, manned launch vehicles, missiles, and rockets and their stages; probes; aerostats and balloons; drones; remotely piloted vehicles; projectiles, torpedoes, and air-dropped bodies

lb - pound, pounds

lbf - pounds force

lead time - the time between the beginning of a process or project and the appearance of its results

LSWG - Laser Safety Working Group

LWO - Launch Weather Officer

MFCO - Mission Flight Control Officer; a United States Air Force officer or civilian who monitors the performance of launch vehicles in flight and initiates flight termination action when required; the direct representative of the Range Commander during the prelaunch countdown and during launch vehicle powered flight

MIL-STD - Military Standard

min - minute

MPE - maximum permissible exposure

GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

MSP - Mission Support Position

NASA - National Aeronautics and Space Administration

NASC - National Aeronautics and Space Council

NFS - near field signature

nm - nautical mile

nominal vehicle - a properly performing launch vehicle whose instantaneous impact point (IIP) does not deviate from the intended IIP locus

normal vehicle - a properly performing launch vehicle whose instantaneous impact point (IIP) does not deviate more than +/- three standard deviations from the intended IIP locus

NOTAM - Notice to Airmen and Mariners

NOTMAR - Notice to Mariners

NSC - National Security Council

NTM - Notice to Mariners, also known as NOTMAR

OD - Operations Directive

OI - Operating Instruction

OP - Operations Plan

operation - a scheduled activity where Range assets are necessary to support Range User requirements for a specified time period

OR - Operations Requirement document

OSTP - Office of Science and Technology Policy

PAFB - Patrick Air Force Base, located in Florida

payload - the object(s) within a payload fairing carried or delivered by a launch vehicle to a desired location; this is a generic term that applies to all payloads that may be delivered from the Eastern Range and Western Range; includes, but is not limited to, satellites, other spacecraft, experimental packages, bomb loads, warheads, reentry vehicles, dummy loads, cargo, and any motors attached to them in the payload fairing

PD - Presidential Directive

P_I - probability of impact

PFDP - Preliminary Flight Data Package

PFPA - Preliminary Flight Plan Approval

PI - Program Introduction

PRD - Program Requirements Document

program - the coordinated group of tasks associated with the concept, design, manufacture, preparation, checkout, and launch of a launch vehicle and/or payload to or from, or otherwise supported by the Eastern and Western Ranges and the associated ground support equipment and facilities

PDR - Preliminary Design Review

psf - pounds per square foot

QE - quadrant elevation

radians - a unit of angular measure

Range Users - clients of Cape Canaveral Air Station and Vandenberg Air Force Base, such as the Department of Defense; non-Department of Defense, United States government agencies; civilian commercial companies; and foreign government agencies that use Eastern and Western Range facilities and test equipment to conduct prelaunch, launch, and impact operations or require on-orbit support

RIIP - the arc ground range from the launch point to the launch vehicle instantaneous impact point

risk study - the analysis of systems (hardware, software, firmware, and procedures) to determine potential hazards that could result in loss of personnel, injury to personnel, loss or degradation of the system or loss of life or injury to the public; *see also hazard analysis*

ROCC - Range Operations Control Center

RSD - Range Safety Display

RSOR - Range Safety Operations Requirements

RTDR - Range Technical Services Data Reduction office

RTS - Range Tracking System

RTSC - Range Technical Services Contractor

RV - reentry vehicle

RWO - Range Weather Officer

sec - second, seconds

GLOSSARY OF ABBREVIATIONS, ACRONYMS, AND DEFINITIONS

single flight azimuth - an operation or mission in which the flight azimuth remains fixed throughout the launch window

sps - samples per second

SPWR - Space Wing Regulation; also SWR

SRM - solid rocket motor

support agency - any agency acting in support of a primary Range User

SVFA - step-wise variable flight azimuth

SW - Space Wing

SWR - Space Wing Regulation

tail winds - winds blowing toward the launch azimuth

TLCF - Technical Laboratory Computer Facility

TMIG - Telemetered Internal Guidance

TNT - trinitrotoluene

T minus Time (T-X) - countdown clock time; T-0 is launch time; time prior to the scheduled launch time not including built-in holds in the countdown; normally measured in seconds, minutes, and hours

UDS - Universal Documentation System

uprange direction - measured in the direction of the negative X axis of the X, Y, Z coordinate system

USAF - United States Air Force

variable flight azimuth - an operation or mission in which the flight azimuth of the trajectory varies either continuously or step-wise (in discreet steps) throughout the launch window

vehicle - launch vehicle and/or payload

waiver - a designation used when, through an error in the manufacturing process or for other reasons, a hardware noncompliance is discovered after hardware production or an operational noncompliance is discovered after operations have begun at CCAS or VAFB

W - weight

W/C_dA - ballistic coefficient; *see also beta*

WR - Western Range

WRR - Western Range Regulation

X dot - velocity in the X direction

Y dot - velocity in the Y direction

Z dot - velocity in the Z direction

REFERENCED DOCUMENTS

30 RANS OI 55-33, *Air Control/Area Control Procedures*

30 SW RSOR, *30th Space Wing Range Safety Operations Requirements*

45 SWI 13-201, *Eastern Range Air Space Management Procedures*

AFI 13-201, *U.S. Air Force Airspace Management*

AFI 91-110, *Nuclear Safety Review and Launch Approval for Space or Missile Use of Radioactive Material and Nuclear Systems*

ANSI Z136.1, 1993, *American National Standard for Safe Use of Lasers*

Department of Defense Directive (DoDD) 3200.11, *Major Range and Test Facility Base*

DoDD 4540.1, *Use of Airspace by U.S. Military Seas*

EWR 127-1, Annex to Chapter 2, *Flight Trajectory and Data Manual*

MIL-STD-1543, *Reliability Program Requirements for Space and Launch Vehicles*

MIL-STD-1629, *Procedures for Performing a Failure Mode Effects and Criticality Analysis*

NASC, *Nuclear Safety Review and Approval Procedures of Minor Radioactive Sources in Space Operations*

PD/NSC-25, *Scientific or Technological Experiments with Possible Large Adverse Environmental Effects and Launch of Nuclear Systems Into Space*

CHAPTER 2
FLIGHT ANALYSIS REQUIREMENTS

2.1 INTRODUCTION

2.1.1 Purpose of the Chapter

Chapter 2 establishes the minimum requirements for trajectory data and system characteristics for vehicles launched from the Eastern Range (ER) and Western Range (WR). The following topics are addressed:

- 2.2 Responsibilities and Authorities
- 2.3 Flight Analysis Policies
- 2.4 Flight Analysis Approvals
- 2.5 Documentation and General Data Requirements
- 2.6 Ballistic Missiles and Space Vehicles Specific Data Requirements
- 2.7 Cruise Missiles and Remotely Piloted Vehicles Specific Data Requirements
- 2.8 Small Unguided Rockets or Probe Vehicles Specific Data Requirements
- 2.9 Aerostat or Balloon Specific Data Requirements
- 2.10 Projectile, Torpedo, Air-Dropped Body, and Device Specific Data Requirements
- 2.11 Air-Launched Vehicle Specific Data Requirements
- 2.12 Collision Avoidance
- 2.13 45 SW Range Safety Requirements for the ER

2.1.2 Applicability

The requirements in this Chapter are applicable to the following programs: ballistic missile and space vehicles; cruise missile and remotely piloted vehicles; small unguided rockets or probes; aerostat or balloon systems; projectiles, torpedoes, non-propulsive air-dropped bodies, or any small devices to be flight tested; intended support plans for ships and aircraft; aircraft and aeronautical systems; directed energy systems; and the launch of large nuclear systems into space.

2.2 RESPONSIBILITIES AND AUTHORITIES

In this Chapter, references to the Commanders, their Staff Offices and Groups refer to both the 45th and 30th Space Wings (SW) unless otherwise noted.

2.2.1 Commanders, 45th Space Wing and 30th Space Wing

In accordance with Department of Defense Directive (DoDD) 3200.11, the Commanders (Range Directors), 45th Space Wing (45 SW) and 30th Space Wing (30 SW) have final authority and responsibility for the safety of launch vehicles and payload launch operations and all other programs conducted on the Ranges. Programs involving the use of large nuclear devices, explosive warheads, and other high risk missions shall be approved by the Commanders.

2.2.2 Chiefs of Safety, 45th Space Wing and 30th Space Wing

The Chiefs of Safety, 45th Space Wing (45 SW/SE) and 30th Space Wing (30 SW/SE) or their designated representatives are responsible for approving the proposed flight plan or mission, determining the need for flight termination systems (FTSs), and developing flight safety criteria.

2.2.3 Operations Support and Analysis, 45th Space Wing and Flight Analysis, 30th Space Wing

Operations Support and Analysis, 45th Space Wing (45 SW/SEOE and SEOS) and Flight Analysis, 30th Space Wing (30 SW/SEY) are responsible for estimating the risks associated with Range operations and determining the constraints necessary to protect life and property for the duration of the scheduled operation. For launch operations, this extends to the time of final impact, the time of orbital insertion, or the time of thrust termination, whichever is greater. **NOTE:** Unless specifically noted in this Chapter, the term *Range Safety* refers to Operations Support and Analysis and Flight Analysis. Operations Support and Analysis and Flight Analysis are responsible for the following:

a. Determining the need for FTSs

b. Reviewing and approving requested flight plans that include operation constraints

c. Reviewing and approving Intended Support Plans (ISP)

d. Reviewing and approving the use of Directed Energy systems

e. Reviewing and approving the use of Large Nuclear systems

f. Developing destruct criteria and Range Safety displays used by Mission Flight Control Officers (MFCOs).

g. Preparing or assigning and evaluating risk studies

h. Providing technical support to the MFCO prior to launch on all operation matters

i. Reviewing and approving launch sites

j. Providing the Range User with instructions on submission and distribution of trajectory data on tapes, floppy disks, or other media

k. Receiving, preparing, and distributing copies of tapes, floppy disks, or other media and printouts or microfiche to Range Support agencies as required

2.2.4 Operations Groups, 45th Space Wing and 30th Space Wing

The Operations Groups, 45th Space Wing (45 OG) and 30th Space Wing (30 OG) are responsible for the following services for Range Safety:

a. For continuing programs, advising Range Safety of operations requiring their support at the earliest practical time

b. Assisting in ensuring the Range User and associated operation support agencies are aware of appropriate Range Safety data requirements

c. As requested, collecting and forwarding data to support Range Safety approvals such as Flight Plan Approval (FPA) and ISPs

d. Issuing hazard notification messages based on Range Safety requirements

e. Coordinating the evacuation, control and/or closure of public parks, oil rigs, railroads, and land, sea and air areas in accordance with Range regulations based on Range Safety requirements

2.2.5 Plans Offices, 45th Space Wing and 30th Space Wing

The Plans Offices, 45th Space Wing (45 SW/XP) and 30th Space Wing (30 SW/XP) are responsible for providing the following services for Range Safety:

a. For new programs, advising Range Safety of operations requiring their support at the earliest practical time

b. Ensuring Range Safety requirements are considered in the planning phase

c. As requested, collecting and forwarding preliminary Range Safety approval data

2.2.6 Range Users

Range Users are responsible for the following:

a. Submitting all data identified as requirements for Range Safety support of planned operations

b. Complying with data submission lead times and Range Safety approval conditions

c. Advising Range Safety of changes to operational scenarios to determine if approvals are affected

d. Providing specific data required for the scheduled operation day

e. Ensuring accuracy and relevancy of all data to support the requests for approvals

f. Providing appropriate media and two printouts of theoretical trajectory data to the lead Range when the program requirements document (PRD) is submitted, when mission trajectories are changed, or when additional trajectories are added. **NOTE:** Requirements for flight trajectory data preparation, submittal, and processing are described in EWR 127-1, Annex to Chapter 2, “Flight Trajectory and Data Manual”.

g. Revising theoretical trajectory data when use of the trajectory, as supplied, will adversely affect the support needed by either planning or operational phases of the Range User program

2.3 FLIGHT ANALYSIS POLICIES

No hazardous condition is acceptable if mission objectives can be attained from a safer approach, methodology, or position.

2.3.1 Flight Analysis Approval

Flight Analysis approval is a necessary prerequisite for conducting operations covered by this Chapter. By itself, Flight Analysis approval does not constitute permission to conduct an operation.

2.3.2 Additional Requirements

Although the requirements in this Chapter are intended to be complete, special launches, flight tests, or circumstances may make it necessary to request additional information.

2.3.3 Flight Termination System

All vehicles launched on the Ranges shall be equipped with an FTS capable of terminating thrust on all stages at any time in flight, up to orbital insertion or until the final impact point is established. The need for flight termination action may be extended to the orbital stages and/or payloads depending on their capability to hazard protected areas. *EXCEPTION: Launch vehicles whose impacts can be adequately controlled by prelaunch restrictions may be excluded from this requirement.* The design of the FTS is discussed in Chapter 4 of this document. Safing of the FTS for the stage that injects the vehicle into orbit shall be accomplished automatically by the vehicle after it has attained orbit and terminated thrust.

2.3.4 Impact Restrictions

a. No launch vehicle, payload, or jettisoned body shall be intentionally impacted on land unless designated as a target and approved by the Chief of Safety. Proposed flights shall be planned and trajectories shaped so that normal impact dispersion areas for such items do not encompass land.

b. If any jettisoned body remains buoyant after impact and presents a hazard to maritime vessels or platforms, a means of sinking or recovering the body shall be provided.

c. For space vehicles, if a stage contains multiple-burn engines, the impact dispersion area corresponding to any planned cutoff before orbital insertion shall be entirely over water. Critical events such as arming of engine cutoff circuits and sending of backup engine cutoff commands shall be sequenced to occur when the impact dispersion areas are entirely over water.

d. In accordance with DoDD 4540.1, all operations shall operate with due regard for the safety of all air and surface traffic. Areas for activities shall be selected so as not to interfere with established air routes and ocean shipping lanes.

2.3.5 Data Submission

In meeting the requirements of this Chapter, much of the information submitted by the Range User may not change from operation to operation. In such cases, the information only needs to be supplied once. However, for each operation, the Range User must state in writing which data are applicable and specify the document, paragraph, and page number where each required item can be found. This statement shall be submitted to Range Safety according to established lead times.

2.3.6 Land Overflight

Whenever possible, the overflight of any inhabited land masses is discouraged and is approved only if operation requirements make overflight necessary, and risk studies indicate probability of impact and casualty expectancy are acceptable.

2.3.7 Trajectory Safety Margins

a. The flight trajectory shall be designed to accommodate Range Safety capability to control launch related risks.

b. A sufficient safety margin shall be provided between the intended flight path and protected areas so a normal vehicle does not violate destruct criteria.

c. During the initial launch phase, the launch profile shall not be so steep that critical coastal areas cannot be protected by standard safety destruct criteria.

2.3.8 Hazard Assessment

The identification of operation-related hazards and the assessment and quantification of risk shall be used to determine operation constraints. **NOTE:** The hazards associated with each source of risk (debris impact, toxic chemical dispersion, and acoustic overpressure) have an associated set of critical parameters and thresholds of acceptability. Changes in launch parameters such as azimuth, payload, and launch site and the need for flight safety controls including the evacuation of personnel, enforcement of roadblocks, and restriction of sea lanes or airspace depend on the results of the hazard assessments.

2.4 FLIGHT ANALYSIS APPROVALS

The Range User should initiate Flight Analysis approval at the earliest practical date to establish that the proposed program is acceptable from a safety standpoint. Early action by the Range User keeps data requirements to a minimum and ensures that the effort and expense of planning a program or computing pre-operation trajectories is not wasted. The specific approval depends on the type of program activity. Developing the safest operation consistent with program objectives can take several months while changes in the proposed plan are made.

2.4.1 Flight Plan Approval

Flight plan approval (FPA) is applicable to the following programs:

a. Ballistic missile and space vehicles

b. Cruise missile and remotely piloted vehicles

c. Small unguided rockets or probes

d. Aerostat or balloon systems

e. Projectiles, torpedoes, non-propulsive air-dropped bodies, or any small devices to be flight tested

2.4.1.1 Flight Plan Approval Overview

The FPA process incorporates two formal approval phases: Preliminary Flight Plan Approval (PFPA) and Final Flight Plan Approval (FFPA).

a. Programs usually fall into two categories: new or existing. New programs include existing programs whose FPA supporting data has changed significantly. New programs shall submit the data requirements for both PFPA and FFPA. Existing programs generally shall submit the data requirements for only FFPA. For either new or existing programs that do not involve long lead times for planning or payload development, approval may, of necessity, occur only a few months prior to the desired operation date.

b. In each FPA phase, Range Safety shall respond to the Range User written request for approval by issuing a letter of approval or disapproval, by requesting that a change in the proposed plan be made or investigated, or by delineating additional data requirements before a decision can be made. After all requested data have been provided and evaluated, the Range User shall be given an approval, conditional approval, or disapproval letter. If the flight plan or mission is approved, the letter shall specify the conditions of approval pertaining to such things as launch azimuth limits, trajectory shaping, wind restrictions, locations of impact areas, times of discrete events, and number of operations for which the approval applies. The approval will be final as long as the operation or operations remain within the stated conditions. If significant changes to the flight plan occur after approval has been granted, further analysis of the revised plan may be necessary. The Range User is responsible for advising Range Safety of any such changes or anticipated changes as early as possible.

2.4.1.2 Preliminary Flight Plan Approval

The flight plan approval process for all new programs begins with an introductory meeting followed by the submittal of required data and a formal written request for a Preliminary Flight Plan Approval (PFPA). Existing programs shall also request a PFPA when previously approved supporting data is not applicable to the planned operation. The purpose of the PFPA is to ensure Range Safety requirements are included in the overall system design and to determine if the specific program is conceptually acceptable. In preliminary meetings, Range Safety can define acceptable flight limits and conditions, specify which parts of the flight plan need special emphasis, and identify requirements applicable to the program. Data regarding anticipated flight trajectories, booster configuration, FTS configuration, and more, are included. Lack of some pertinent data should not be cause for delaying the initial written request, particularly if preliminary discussions have not been held. The Range User should begin PFPA action during the Preliminary Design Review (PDR) phase of program planning or, in any event, immediately after Range Safety has replied to the Program Introduction in a Statement of Capability. For new programs, the PFPA usually occurs at least two years (one year for existing programs) prior to the planned operation.

2.4.1.3 Final Flight Plan Approval

The Final Flight Plan Approval (FFPA) is applicable to each program operation. The FFPA is based on detailed analysis of the operation objectives, vehicle performance, and other data items required. In response to the Range User request, the FFPA is issued when the Chief of Safety is satisfied that a specific operation can be supported within the limits of flight safety control capabilities to provide positive protection to life and property. Any constraints or conditions identified in the PFPA may be superseded by those stated in the FFPA. The FFPA applies to a specific operation and does not guarantee that similar operations will receive an FFPA. If a program consists of identical operations, a blanket FFPA may be granted that would remain in effect throughout the life of the program as long as the operations remain within the specified safety constraints. The request for FFPA and the supporting data are typically received by Range Safety at 120 calendar days (new programs), or 60 calendar days (existing programs), prior to the planned operation. Past data submittals may be referenced if that data has not changed from previous operations.

2.4.2 Ship/Aircraft Intended Support Plan Approval

2.4.2.1 Purpose

The purpose of the ISP approval is to ensure maximum safety consistent with the operation objectives. To the extent possible, this means that support positions and flight plans should be established outside impact limit lines. When the required support data cannot be collected from such remote locations, support positions located in relatively hazardous areas must be carefully planned to minimize the ship or aircraft hit probability. Hazards to ships and aircraft exist primarily in the launch area, along the flight azimuth where jettisoned stages and components reenter and breakup, and in the target area where reentry vehicles and final stages impact.

2.4.2.2 Applicability

ISP approval is applicable to each ship and aircraft supporting an operation requirement identified in the Universal Documentation System (UDS) or participating in an operation on a non-interference basis. Policies and procedures for control of test support aircraft are given in 45 SWI 13-201 or 30 RANS Operating Instruction (OI) 55-33.” Similar regulations for ships do not exist.

2.4.2.3 ISP Development and Submittal

ISPs for ships and aircraft shall be developed either by the Range User or by support agencies that are responding to requirements contained in the Program Requirements Document (PRD) or the Operation Requirements (OR) document. In either case, the developing organization shall furnish the ISP for review and approval, either directly to Range Safety or through the Range Squadron.

2.4.3 Directed Energy Plan Approval

2.4.3.1 Purpose

The purpose of the Directed Energy Plan (DEP) approval is to ensure the operation is conducted safely with consideration for the operation requirements and national need.

2.4.3.2 Applicability

The DEP approval applies to programs using directed energy systems. These systems include, but are not limited to, lasers and neutral particle and ion beams, with any combination of surface, air, or space locations for the energy source and target. In this Chapter, the term *laser* is used as a generic reference to all directed energy systems. **NOTE:** Laser design, test, and documentation requirements are also addressed in the **Laser System Design Requirements** section of Chapter 3 of this document.

2.4.3.3 Categories Subject to Review

In general, those laser operations in the following categories are subject to review:

a. Laser operations requesting Range support through the provisions of the UDS.

b. Laser illumination, for which an Operations Directive (OD) does not exist, conducted in conjunction with a scheduled Range operation for which an OD does exist.

c. Laser operations having the potential to impair Range Safety controls or reduce the reliability of Range Safety systems.

2.4.3.4 Laser Program Evaluation

a. At the ER, the laser program is evaluated by the Laser Safety Working Group (LSWG), made up of representatives from each section of the Safety Office. The LSWG was chartered to provide a central and coordinated venue for assessing hazards associated with specific categories of laser operations. It is also responsible for providing customer guidance towards satisfying safety requirements.

b. At the WR, the laser program is evaluated by Range Safety. Responsibilities include:

1. Providing guidance for the Range User in satisfying safety requirements

2. Assessing hazards associated with specific categories of laser operations

3. Recommending laser safety constraints

4. Issuing an advisory laser operation approval letter

2.4.3.5 DEP Submittal

a. Requests for DEP approval shall be forwarded directly to Range Safety or through either the Plans Office for new programs or the Range Squadron for existing programs.

b. Lead times and requirements may vary and will be tailored depending on the specific characteristics of the system and proposed operating scenario. Lead times for data requirements reflect the dependence of mission success on planned laser operations. For instance, laser operations performed on a non-interference basis using scheduled launches as a target of opportunity will have lead times different than laser activities that are integral to a scheduled operation. Laser operations considered mandatory by the Range User shall be included as part of the Program Introduction (PI). If the laser operation is not mandatory in accordance with Range User requirements, the initial request for laser program approval is desired at least one year prior to the planned operation date. Requests for Range Safety review of recurring laser operations are desired 30 calendar days prior to each planned operation date. Modifications to existing laser systems or changes to current operating plans should be discussed with Range Safety during the planning phase to determine the need for additional data requirements and establish mutually agreeable lead times for submission of additional data.

2.4.4 Large Nuclear Systems Approval

Range Users employing radioactive material that exceed Category A established by the Office of Science Technology Policy (OSTP) shall comply with Presidential Directive/NSC-25. The Range User shall provide Range Safety with a copy of the following documents. **NOTE:** Nuclear system design, test, and documentation requirements are also addressed in the **Radioactive (Ionizing Radiation) Design Requirements** section of Chapter 3 of this document.

a. Environment Impact Statement: L-3 years

b. Final Safety Analysis Report: L-1 year

c. Interagency Nuclear Safety Review Panel (INSRP) Safety Evaluation Report: L-7 months. **NOTE**: In the event that the INSRP is not impaneled by the OSTP, the provisions of AFI 91-110 (21 Mar 94), "Nuclear Safety Review and Launch Approval for Space or Missile Use of Radioactive Material and Nuclear Systems," shall be performed by the USAF Directorate of Nuclear Surety and the results provided to Range Safety in lieu of the INSRP Safety Evaluation Report.

d. Certification of Presidential approval for flight: L-10 days. A copy of the OSTP approval letter or the National Security Council approval letter meets this certification requirement.

2.5 DOCUMENTATION AND GENERAL DATA REQUIREMENTS

This section lists the documentation and general data requirements applicable to all programs covered by this Chapter. Sections 2.6 through 2.11 list the specific data requirements for each program operation.

2.5.1 Security

The Range User shall provide a security classification guide for all classified program information.

2.5.2 Lead Times

Before Range Safety approval is granted, the Range User must provide required data in specified formats in accordance with lead times in Table 2-1. In some cases, other Range regulations may establish lead time requirements that exceed those established here. Lead times may be modified depending upon the complexity of the program. If the requirements are not provided within the lead time specified, Range Safety may not be able to prepare all necessary safety criteria in time to support a proposed operation. In this event, the operation shall not be conducted until Range Safety can make adequate safety preparations.

2.5.3 Items Marked With Double Asterisks

In this Chapter, certain required data items are marked with double asterisks (**); for example, the time interval at which turn angle graphs are required. The asterisks mean the magnitude, inter-

TABLE 2-1
Documentation Lead Times and Data Requirement References

Vehicle/Missile	Lead Time Before Launch (Calendar Days)

TABLE 2-1
Documentation Lead Times and Data Requirement References

Vehicle/Missile	Lead Time Before Launch (Calendar Days)
Ballistic Missile:	
PFPA (New/Existing)	2 Y/ 1Y
FFPA (New/Existing)	120 D/60 D
Space Vehicle: Single Flight Azimuth	
PFPA (New/Existing)	2 Y/1 Y
FFPA (New/Existing)	120 D/60 D
Space Vehicle: Variable Flight Azi-muth	
PFPA (New/Existing)	2 Y/1Y
FFPA (new/Existing)	12M/6M
Project Firing Tables	9 D
Cruise Missile/Remotely Piloted Vehicle:	
PFPA (New/Existing)	2 Y/1 Y
FFPA (New/Existing	120 D/60 D
Small Unguided Rocket:	
PFPA (New/Existing)	2 Y/1 Y
FFPA (New/Existing)	120 D/60 D
Aerostat/Balloon:	
PFPA (New/Existing)	2 Y/1 Y
FFPA (New/Existing)	120 D/60 D
Projectile, Torpedo, Air-Dropped Body or Device:	
PFPA (New/Existing)	2 Y/1 Y
FFPA (new/Existing)	120 D/60 D
Ship and Aircraft ISP	20 Days
Directed Energy Systems (New/Existing)	1 Y/30 D
Large Nuclear Systems	See para 2.4.4

All lead times are based on the standard calendar year

val, or duration for the required item varies from program to program and that the value given is typical. For each program, Range Safety provides the Range User with the particular value to use for each parameter marked with double asterisks.

2.5.4 Range Tracking System Performance Requirements

The Range Tracking System (RTS) is made up of the hardware, software, and manpower required to transmit, receive, process, and display launch vehicle data required for Range Safety purposes. An RTS including at least two adequate and independent instrumentation data sources is mandatory and shall be maintained from T-0 throughout each phase of powered flight up to the end of Range Safety responsibility. See Chapters 4 and 7 for additional requirements.

2.5.4.1 Tracking Source Adequacy

Each tracking source provided for Range Safety shall provide real-time state vector (position and velocity) accuracy, timeliness, and reliability so that when extrapolated to IIP space, the following criteria are met:

2.5.4.1.1 Accuracy. The three-sigma IIP uncertainty resulting from all error sources shall be no greater than the following:

a. ER: The launch area IIP uncertainties shall not exceed 100 ft in either crossrange or downrange directions For downrange IIP uncertainties, the displayed crossrange IIP error shall not exceed one-half percent of the vacuum impact range and the displayed downrange IIP error shall not exceed five percent of the vacuum impact range. The allowed error values are computed as follows:

$$\text{Crossrange error} = \begin{cases} 100\text{ ft}, & 100\text{ ft} \geq 0.5\%\text{ RIIP} \\ 0.5\%\text{ RIIP}, & 100\text{ ft}, < 0.5\%\text{ RIIP} \end{cases}$$

$$\text{Downrange error} = \begin{cases} 100\text{ ft}, & 100\text{ ft} \geq 5.0\%\text{ RIIP} \\ 5.0\%\text{ RIIP}, & 100\text{ ft}, < 5.0\%\text{ RIIP} \end{cases}$$

b. WR: The Launch Area IIP uncertainties shall not exceed 1000 ft. The midcourse IIP uncertainties shall not exceed 1 percent of the IIP range. The terminal area IIP uncertainties shall not exceed 7000 ft. **NOTE 1:** The accuracy is given in terms of the radius of a circle that contains three-sigma of all possible instantaneous impact points. **NOTE 2:** The launch area accuracy applies until the hazardous debris impact areas are entirely over water. **NOTE 3:** The terminal area accuracy applies only to ballistic vehicles with a maneuverable upper stage targeted for the Kwajalein Missile Range (KMR).

2.5.4.1.2 Timeliness.

a. The IIP display update rate shall be at least 10 samples per second (sps), and each update shall meet the requirements of paragraphs 2.5.4.1.1 and 2.5.4.1.2 *b*.

b. The time delay between vehicle event and firing of the vehicle ordnance, exclusive of the MFCO reaction time, shall be within the total Range Safety System response time budget. This budget includes hardware and software delays inherent to both airborne and ground equipment. The budget for the ER is 1.5 sec and 3.5 sec depending on the time of flight and Range Safety System configuration for each operation. The WR budget is 1 sec except for ballistic operations targeted for the Kwajalein Atoll and orbital operations with a low launch azimuth (typically less than 170°) for which the budget is 500 milliseconds during critical portions of flight.

2.5.4.1.3 RTS Reliability (Ground Segment only). The reliability of the RTS ground segment shall be at least 0.999 at a 95 percent confidence level for a 1 h duration during the period of Range Safety responsibility.

2.5.4.2 Tracking Source Independence

Each tracking source provided for Range Safety shall be electrically, mechanically, and structurally separate from the vehicle guidance and telemetry systems and any other tracking source, so that one tracking source will not influence another tracking source. See exceptions in Chapter 4.

2.5.5 Telemetered Vehicle Information

2.5.5.1 Telemetered Inertial Guidance Data

Telemetered Inertial Guidance (TMIG) data is a mandatory tracking source for programs using a launch vehicle inertial guidance system. The TMIG data is required in the standard Inter-Range Instrumentation Group (IRIG) format at a 20 sps update rate from T-0 through the end of Range Safety responsibility.

2.5.5.2 Telemetry Data

Telemetered performance, guidance, and FTS data are required. The items required in real time shall be defined by Range Safety during the initial meeting with the Range User. Data shall typically include, but are not necessarily limited to:

2.5.5.2.1 Performance Data: Chamber pressure, fuel pressure, accelerometer outputs, steering information, and discrete events such as staging and payload or reentry vehicle (RV) release

2.5.5.2.2 Guidance Data. Position (X,Y,Z), velocity ($\dot{X}, \dot{Y}, \dot{Z}$), guidance phase and internal cycle status (for example, major and minor cycles), steering commands, accelerometer inputs and sums, malfunction detection indicators and discreet initiations

2.5.5.2.3 FTS Data: Received signal strength and decoded outputs or commands

2.5.6 Risk Study

If deemed necessary, the Range User may be required to conduct a risk study (hazard analysis).

2.5.6.1 Rationale for Conducting a Risk Study

Range Safety approval is granted or a deviation or waiver request is approved when, in the Range Director's judgment, the hazards associated with the proposed operation appear reasonable and the objectives of the operation cannot be met in a safer fashion. A risk study quantifies the hazards associated with the proposed operation in terms of the probability of impact and expectation of casualty to protected areas and serves as one basis for deciding if hazards are reasonable. To complete the study, most of the data required for program approval (for example, debris data, failure rates, trajectory, turn data) must have already been computed.

2.5.6.2 Conditions Requiring a Risk Study

For FPA, a study may be required if the flight plan involves any of the following hazardous conditions:

a. Direct overflight of land prior to thrust termination or orbital injection

b. Flight so close to land that destruct criteria may be violated by a normal vehicle or debris could impact land if a destruct event were to occur

c. A launch area trajectory so steep that critical coastal areas or launch area facilities cannot be protected by standard destruct criteria without endangering a normal missile.

d. A period during flight when land areas cannot be protected from a malfunctioning vehicle because the vehicle has no FTS, premature separation destruct capability, or Range Safety System capability is surpassed by the vehicle performance

2.5.6.3 Risk Study Components

At a minimum, the study shall consist of the major components listed below. Additional procedures and requirements pertaining to the study will be specified during the early part of the approval process.

a. Determination of failure probabilities and failure density functions; a description of how these functions were computed and the failure modes considered

b. Computation of dwell times over land

c. Probability of impact density functions for each failure or malfunction mode in terms of downrange and crossrange components

d. A list of all population centers or the population density along the flight path that could have debris impacting on them after a destruct event. The list shall include the name of the population center, area (A_p) in ft^2, population center centroid in geodetic latitude and longitude, the total number of persons in the population center (N), and the number of persons in each shelter category within each population center. The shelter categories are defined as follows:

1. Heavy - Blockhouse bunkers and heavily reinforced structures

2. Medium - Buildings with concrete or reinforced roofs, and all floors except the top floor in multi-story buildings

3. Light - Single story buildings, trailers, and top floors of multi-story buildings

4. Exposed - No protection from falling debris

e. Evaluation of casualty area (A_C) based on vehicle breakup analysis.

f. Probability of Impact (P_I) for each population center computed by summing the individual failure mode probabilities of impact over all fragment groups; the failure rates for each of the failure modes and the flight dwell time over each population center are included in the computation.

g. Casualty Expectation (E_C) for each population center. Total population center E_C is computed by summing the E_C values over all fragments affecting each population center. In simplified terms, not accounting for possible sheltering of persons,

$$\text{Total } E_C = N / A_p * \sum_{i} \left(P_{I_i} * A_{c_i} \right)$$

Where: i is a fragment in the fragmentation group

h. Sample calculations and supporting documentation

2.5.7 Statement of Program Justification

The Range User may be asked to provide the following additional supporting data and justification before an approval can be made. The need for this information will be established in preliminary discussions or in the Chief of Safety's response to a written request for approval.

a. Complete statement of the operation objectives

b. Statement about the operation objectives that will not be met if the proposed plan must be modified as suggested by Range Safety or is not approved

c. Alternate or modified plans that will accomplish the operation objectives

d. Effects on the operation such as cost, schedule, data requirements, vehicle reliability, reserve propellants, launch window, if the plan must be modified or if the plan is not approved

e. Other data the Range User may wish to submit

2.5.8 Flight Plan Approval Data Requirements

Data requirements for PFPA and FFPA are found in two sections. The first is a general section that applies to all programs, and the second is a detailed section that applies to a specific program (see Sections 2.6 - 2.11). All sections may be tailored by Range Safety as required. The PFDP and the FFDP are submitted in support of the PFPA and FFPA, respectively. The data packages may be submitted in any convenient format. The following general format, that conforms to the order in which requirements are established, is suggested for any Range User who desires a standard submission form. If this format is adopted and the information submitted in response to a requirement cannot easily be placed in the data package, it should be made an appendix to the specific part. For example, the magnetic tapes and listings for trajectories would be an appendix to Part 3.

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Part 1: Introduction
Part 2: General Vehicle Data
Part 3: Trajectory Data
Part 4: Additional Data

2.5.8.1 Preliminary Flight Data Package

These data requirements apply to requests for PFPA for all missiles, space vehicles, rockets, and other items as specified in paragraph 2.4.1. The program-specific PFDP requirements in Sections 2.6 - 2.11 are also required before a PFPA can be issued. The need for additional information will be established in early discussions with the Range User or in the response to the written request for PFPA. The request for PFPA shall specify the operation designation, intended operation date, and references to all applicable supporting data products. In meeting these requirements, reference may be made to documentation previously submitted. If this is done, the Range User shall specifically identify applicable supporting data, and indicate the document, page number, and paragraph where each required item can be found.

2.5.8.1.1 General Requirements.

a. Basic program description and objectives including number, designation, and purpose of operations(s) for which the proposed flight plan is applicable

b. General operation scenarios and proposed target areas and a statement indicating whether the proposed trajectory (or flight plan) is similar to some prior operation

c. Intended launch or flight test date(s)

d. Map and listing of downrange and cross-range vacuum instantaneous impact points for each second of powered flight time

e. General description of launch vehicle and payload in sufficient detail for hazard assessment providing the following information:

1. Type, weight, and TNT equivalency of propellants

2. Description of ordnance items

3. Description of toxic and radioactive materials

4. Characteristics of high pressure vessels, lasers, and batteries

5. Description of materials, thickness, and safety factors of pressure vessels

6. Thrust and burn times of motors and thrusting devices

7. Description of guidance and control systems

8. Drawings and diagrams showing structural arrangement and layout of significant components in each stage or payload

f. General description and location of the airborne FTS (made up of the command and automatic destruct subsystems), or statement indicating that the planned system is similar to one already in use. **NOTE:** Range Safety must be involved prior to the Preliminary Design Review time frame if a new design is to be considered.

g. Preliminary estimate of fragment characteristics such as number, composition, dimensions, and weight due to all potential modes of vehicle breakup such as destruct, and aerodynamic loading

h. Tracking aids such as C-Band transponder installed in the vehicle that can be used for flight safety purposes and their locations in the stages or sections

i. Telemetry measurement listing and data word definitions

j. Description of launch site facilities, support buildings, and the structural integrity information for each of these

k. Geodetic latitude, longitude, and designation of proposed launch site, or location on the earth's surface for launches that occur above or below the earth's surface. If launch or test initiation can occur inside an area rather than at a single specified location, this area shall be defined.

l. Launch azimuth for single azimuth launches or desired azimuth sector(s) for variable azimuth launches

m. Estimates of the nominal impact point, and the three-sigma drag-corrected impact dispersion area for each jettisoned body

n. Buoyancy analysis of all impacted, jettisoned bodies. For bodies that remain buoyant after impact and present a hazard to maritime vessels or platforms, a means of sinking or recovering the body is required. If recovery is desired, a recovery procedure shall be identified.

2.5.8.1.2 Reliability and Malfunction Analysis Data Requirements. Reliability of each stage and probability of a normal mission or failure rate data for each stage shall be provided. The following data shall be included:

a. Description of failure modes that can result in abnormal impacts. An analysis of all subsystems shall be made to determine failure modes that would result in a catastrophic event. Typical malfunctions that should be considered include failure of the hydraulic and electrical systems, failure of the guidance and control system, failure of separation mechanisms between stages, failures that lead to premature thrust termination, overshoot, or shifting of the platform reference.

b. An estimate of the probability of occurrence or failure rate (versus time) for each failure mode; any other information considered pertinent with respect to critical portions of flight, such as vehicle stability characteristics and structural limits

c. Description of all credible failed vehicle response modes. A response mode is a category of vehicle dynamic response, including vehicle breakup, that results from one or more failure modes. At a minimum, the response modes should include on-trajectory failures such as thrust termination and explosion and malfunction turn (loss of thrust vector control, tumble turn, nozzle burn-through) failures. On-trajectory failures should be subdivided according to the type of breakup (for example, aerodynamic or explosive) that will result. Malfunction turns should be subdivided into tumble turns and trimmed turns if trimmed turns are a credible response mode.

d. Summary of past vehicle performance giving number launched, launch location, number that performed normally, behavior and impact location for any that malfunctioned, time and nature of malfunction, and corrective action

2.5.8.1.3 Propellant Description. If a vehicle has the capability of exploding as a result of self-initiation, FTS activation, or ground or water impact; or if a vehicle uses propellants that are toxic in gaseous or vapor states due to combustion or release to the atmosphere, the following data are required:

a. Types of propellants or a statement indicating the same propellants are already in use

b. TNT equivalency versus flight time and explosion scenario for each separate stage (or motor) and each possible combination of stages that could result from malfunction conditions

c. The probability of explosion versus flight time for each of the following: self-initiation, FTS activation, and ground or water impact

d. Description of methods used to minimize the possibility of explosion

e. Time of day when launches will be scheduled and the number of launches

f. Maximum total quantities of liquid and solid propellants

g. Nominal vehicle altitude (meters AGL) versus time through 3,000 m in the following format:

$$t = a * z^{b} + c$$

Where:

t = time (sec) after initial ignition

z = height (m) of the vehicle above the launch pad, and a, b, c are coefficients found by a least squares fit to an estimated time-height profile for this booster.

h. Heat (cal) released by the solid fuel when combusted to an equilibrium state of the exhaust products and the time required for the exhaust products to reach chemical equilibrium

i. Burn time and expenditure rate of solid propellant for nominal launch and a catastrophic abort occurring at lift-off, including fuel fragmentation and expenditure rate assumptions used to generate the atmospheric abort parameters

j. Liquid propellant expenditure rate (grams per sec) for nominal launch

k. Fractions of the following species released from liquid and solid propellant combustion during nominal and catastrophic scenarios: hydrogen chloride, carbon dioxide, carbon monoxide, aluminum oxide, hydrazine, unsymmetrical dimethylhydrazine, monomethylhydrazine, nitrogen tetroxide, nitrogen dioxide, nitrosodimethylamine, and formaldehyde dimethylhydrazine

l. Initial Exhaust Cloud Data. The following information is needed to specify the initial exhaust cloud parameters. These values describe the exhaust ground cloud when the horizontal momentum produced by the ducting in the launch mount becomes negligible compared to the buoyant forces within the cloud for the nominal launch scenario.

1. Initial exhaust ground cloud central radius in meters for nominal launches and radius of area over which solid fuel fragments are dispersed for catastrophic abort cases

2. Vertical velocity of cloud centroid in meters per sec for nominal and catastrophic cases

3. Initial ground cloud centroid height in meters AGL

2.5.8.1.4 Explosive Reentry Vehicle or Warhead Information. An operation that includes the use of an explosive reentry vehicle (RV) or warhead shall not be conducted without the approval of the Range Director. For these operations, the following data are required:

a. A complete justification for the proposed operation

b. The proposed position and altitude of the RV or warhead detonation point

c. The effects of the detonation on the missile and RV or warhead in terms of number, weights, cross-sectional areas, ballistic coefficients, and velocities imparted to the pieces

d. The impact dispersion area for all fragments including diffusion and dispersion of any toxic or radioactive clouds or fragments and the radiation exposure characteristics

2.5.8.2 Final Flight Data Package General Requirements

These data requirements apply to requests for FFPA for all missiles, space vehicles, rockets, and other items as specified in paragraph 2.4.1. The program specific FFDP requirements in Sections 2.6 - 2.11 are also required before a FFPA is issued. The FFDP shall include items that were changed from or not provided in the PFDP. The FFDP is made up of the data requirements used to produce the final set of operation rules and flight control criteria and ensures all data complies with the conditions of the PFPA and data format requirements. The request for FFPA shall specify the operation designation, intended operation date, and references to all applicable supporting data products. In meeting the FFPA requirements, some of the information submitted by the Range User may not change from the PFDP or from operation to operation. In such cases, the information need be supplied only once. However, for each operation, the Range User shall state in writing which supporting data are applicable and specify the document, page number and paragraph where each required item can be found. In other cases where the proposed plan deviates from the PFPA or previously accepted limits, additional data shall be provided.

2.5.9 Statement of Vehicle Performance

Within one to three months after an operation has been conducted, a statement of vehicle performance is required. This information may be provided by letter or by lending Range Safety the performance evaluation documents prepared for other purposes. This is information needed for evaluation of vehicle performance capabilities upon which changes in safety abort criteria are based and for updating the failure rate information used in the various risk analysis models. Information required includes:

a. Qualitative statement about the performance of each stage and various subsystems

b. Failures that occurred and resulting flight conditions produced

c. Probable cause of failure and corrective action taken

d. Impact points for stages

e. Miss distances for weapon system tests and orbital parameters for space vehicle flights

f. Comparison of planned and achieved cutoff conditions for each stage

g. Performance of on-board safety instrumentation systems

2.5.10 Intended Support Plan Data Requirements

For operations requiring support aircraft or ships, the following additional information is required 20 calendar days prior to the mission. All identifying points and positions shall be time correlated using the operation start time as a reference.

2.5.10.1 Aircraft Flight Profile Information

a. Type of aircraft

b. Aircraft physical dimensions as described in Jane's aircraft publications. The following data shall be provided as a minimum:

1. 1/2 wing span - the length of the wing measured from the fuselage to the wing tip edge

2. Maximum width of fuselage measured in the top planform view

3. Average depth of wing measured in the side planform view

4. Average fuselage depth measured in the side planform view

5. Area measured in the top planform view

6. Perimeter measured in the top planform view

c. Call sign ("N" number, tail number, etc.)

d. Warning area and mission area penetration points (entry and exit)

e. Holding fixes and altitudes

f. Primary and alternate Mission Support Position (MSP) including geodetic latitude, longitude, heading, speed, and time of arrival

g. Written and graphic flight path location describing the maneuvers within 200 miles of the MSP giving orbit or loiter locations, positions along ground track in latitude and longitude, turn points, turn radii where applicable, speeds, and headings

h. Course, speed, and altitudes to the MSP; (the terminal end of the data run)

i. Departure route after mission completion, including maneuvers after MSP for departure to recovery base

j. Final staging and recovery base

2.5.10.2 Ship Cruise Profile Information

a. Class of ship

b. Dimensions of ship measured in the top planform view

c. Call sign (registration number, name, etc.)

d. Warning area and mission area penetration points (entry and exit).

e. Primary and Alternate MSPs including geodetic latitude, longitude, heading, and speed

f. Course and speed to the MSP (terminal end of the data run)

g. Planned location (support plan) both written and graphic, of vessel during period from launch until operation termination or impact

2.5.11 Directed Energy Plan Data Requirements

The data requirements in this section apply to all forms of directed energy systems. **NOTE:** Laser design, test, and documentation requirements are also addressed in the **Laser System Design Requirements** section of Chapter 3 of this document. Reasonable and prudent operational procedures shall be established so that hazards from laser operations present virtually no risk to the general public. A risk study may minimize the effect of the following operational procedures on the program.

2.5.11.1 Laser Operational Procedures

2.5.11.1.1 Avoidance Volume. The avoidance volume shall encompass that portion of the laser beam that is capable of causing either permanent or temporary ocular impairment. The radial distance of the avoidance volume from the center of the laser beam depends on several variables, including laser operating parameters, time delays between aircraft detection and laser termination, average aircraft speeds, and reliability of system controls.

2.5.11.1.2 Airspace Surveillance. Organizations conducting laser operations shall provide for an airspace surveillance capability and procedures that ensure the laser operation can be terminated before a non-participating aircraft enters the predefined laser beam avoidance volume.

2.5.11.1.3 Airspace Control. The *American National Standard (ANSI) for Safe Use of Lasers,* Z136.1, 1993, paragraph 4.3.11.2 requires coordination with the Federal Aviation Administration when laser programs include the use of Class 3a, 3b, and 4 lasers within navigable airspace. For Range Safety purposes, airspace control is a desirable safety measure; however, it is considered a secondary protection measure to surveillance requirements. Airspace controls shall be initiated by Range Safety when the value added to safety is justifiable.

2.5.11.1.4 Laser Beam Azimuth and Elevation Restrictions. Laser beam azimuth and elevation restrictions shall be defined so that the laser beam avoidance volume is constrained to airspace for which an approved surveillance capability has been established.

2.5.11.1.5 Weather Constraints. The laser operation shall be terminated during periods when weather conditions obstruct or adversely affect an approved surveillance method.

2.5.11.1.6 General Data Requirements. The following data are required for each operation or group of operations. Additional data may be required depending on the laser system.

a. Complete description of surveillance methods, surveillance range limits, and a description of the procedures used to terminate laser operations when necessary

b. General information on the purpose of the operation

c. Description of the laser and its operation

d. Laser classification in accordance with ANSI Z136.1

e. Description of operation scenarios and proposed target areas, if known

f. Copies of safety analyses and test procedures conducted on the system

g. Laser Emission Characteristics

1. Mode of operation (continuous wave or pulsed)

2. Wavelength (meters)

3. Energy per pulse in Joules for pulsed lasers, or power in Watts for continuous wave lasers

4. Pulse repetition frequency (Hertz)

5. Pulse width and pulse separation (sec)

6. Beam diameter between 1/e points at the exit aperture, or at the waist if convergent beam (centimeters)

7. Beam divergence angle at the aperture or waist (radians)

h. Number and designation of laser operations to which the proposed operation applies

i. A statement indicating whether the proposed operation is similar in its safety aspects to that of some prior operation for which documentation is available

j. Intended operation dates

k. Functional description of the target acquisition and laser firing process and of any error/-failure detection and correction or termination capability, including its reliability and response time

2.5.11.2 Nominal Mission Data

2.5.11.2.1 Scenario Type. (Can be any combination of the following):

a. Fixed laser and/or target

b. Moving laser and/or target

2.5.11.2.2 Laser and Target(s) Position Data.

a. Fixed - latitude, longitude, and altitude where the laser beam exits the protective housing and of each target

b. Moving - position and velocity vector versus time of each object in an Earth Centered Rotating (EFG) Coordinate System.

2.5.11.2.3 Nominal Operation Scenario Data.

a. Desired operating azimuth and elevation sectors

b. Event times; for example, acquisition, arming and firing on/off times

c. Duration of each laser firing (sec)

d. Slew rate (radians/sec)

e. Hardware and software stops (angles from forward direction, radians)

f. Pointing accuracy (radians); brief description of laser beam pointing aids including their location

g. Laser platform/vehicle attitude control accuracy (static, radians; dynamic, radians/sec)

2.5.11.2.4 Target Data.

a. Target size - radius or height, width, and length

b. Orientation - angle of each target surface with respect to the incident beam

c. Type of reflection possible such as specular or diffuse

d. Reflection coefficients

2.5.11.2.5 Exposure Controls. (Calculated in accordance with ANSI Z136.1)

a. Maximum permissible exposure (MPE) level, nominal optical hazard distance in a vacuum, and other applicable hazard ranges for each laser

b. Description of the maximum region around each target that can be hazarded during a nominal operation

c. Reflection characteristics of other significant objects in the hazard region around each target. **NOTE:** The hazard region is the zone where the laser radiation levels may exceed the MPE level.

2.5.11.3 Risk Study Data Requirements For A Non-Nominal Mission

If a risk study is required, the following data shall be submitted:

2.5.11.3.1 Probability of Occurrence Data. The probability of occurrence versus time of operation for each of the following generic hazard modes (modes of beam control error or failure): Pointing Error, Inadvertent Slewing, Premature Firing, Delayed Firing, Beam Focusing Error, Loss of Focus, and other modes such as Wrong Target Acquisition applicable to the system. If the probability of occurrence is non-zero for any of these hazard modes, then probability distributions for the random hazard mode parameters describing how each mode can occur over time shall be provided. The following parameters describe each of the stated failure modes.

a. Pointing Error Hazard Mode: offset angle (radians) between the correct laser to target pointing direction and the incorrect pointing direction (angle assumed constant during a firing)

b. Inadvertent Slewing Hazard Mode

1. Time (sec) during firing at which the inadvertent slewing starts

2. Azimuth angle (radians, measured from North) of the slew plane. It is assumed that, over time, the laser-to-target line remains contained in a plane.

3. The angular rate (radians/sec) of slewing in the plane (rate assumed constant)

4. Duration of the slewing (sec), if other than that of the nominal firing time remaining after the start of the slewing

c. Premature Firing Mode: number of seconds prior to the nominal start time that laser firing occurs *d*. Delayed Firing Termination Mode: number of seconds after the nominal termination time that laser cutoff occurs

e. Beam Focusing Error Mode: range (meters) along the laser-to-target vector at which the convergent beam is misfocused. The incorrect range can either be too long or too short relative to the nominal focus range.

f. Loss of Focus Mode

1. Time (sec) during firing at which the loss of focus occurs

2. Beam divergence angle (radians) that measures the spreading of the beam (assumed to remain centered on the laser-to-target vector)

2.5.11.3.2 Failure Modes, Effects, and Criticality Analysis. Applicable hazard modes shall be defined and documented by a failure modes, effects, and criticality analysis (FMECA) in accordance with MIL-STD-1543 and MIL-STD-1629 or the equivalent. Their probabilities of occurrence and the probability distributions of their descriptive parameters shall be quantified with fault tree analyses or the equivalent. The level of analysis conducted in each case shall be the level at which appropriate component error/failure data are available. If necessary for confidence in the results, analyses of the effects of the uncertainties in the component data shall be carried out.

2.5.11.3.3 Alternative Data Submission. The Range User may arrange to have the risk study done by Range Safety. The following data shall be provided to support this option:

a. System design description and performance data and functional and reliability block diagrams for portions of the system affecting beam control, including platform attitude control

b. Associated component (including hardware, software, and human) reliabilities or, as a minimum, component and component environment descriptions allowing the estimation of these reliabilities

2.5.11.4 Coordination with the US Space Command Space Control Center

Coordination with the US Space Command CMOC/J3OXY (Special Operations Section) is required for all Class 3 and 4 lasers operated outside of a confined laboratory environment. For these systems, unless waived by the CMOC/-J3OXY (Special Operations Section), firing time coordination shall be accomplished to verify that on-orbit objects of national interest are not affected by the laser operation.

2.6 BALLISTIC MISSILES AND SPACE VEHICLES SPECIFIC DATA REQUIREMENTS

The trajectory and performance data requirements in this section apply to ballistic missiles and space vehicles. The following items are required for each missile/space vehicle flight or group of similar flights and should be updated as changes to vehicle configuration occur or revised information becomes available.

2.6.1 Preliminary Flight Data Package Requirements

These data are required in addition to the data requirements specified in section 2.5.8.1.

2.6.1.1 FTS Requirements Evaluation

The threat from any payload or stage without an FTS shall be analyzed to determine the risk associated with a malfunctioned launch vehicle whose payload or stage may separate prematurely. The Range User shall provide a residual thrust dispersion analysis and an intact impact analysis for the payload or stage deemed hazardous by Range Safety. The results of these analyses shall be provided to Range Safety three****** months prior to the time that a waiver of the FTS is required. If the resulting dispersions are small enough for inclusion as offsets in the Range Safety destruct computations, there may be no need for a risk study. In any event, before making a residual thrust dispersion or intact impact analysis, the Range User shall reach agreement with Range Safety on the assumptions and approaches to be used and the output data required. Analyses shall consider the following:

a. Functional description of structural, mechanical, and electrical inhibits or safeguards for preventing premature separation and ignition of payload or stage propulsion systems; extent to which such inhibits are independent; simplified schematics and operational description of propulsion system ignition circuits; extent to which circuits and systems are shielded

b. Failure modes that can lead to premature separation and/or ignition of upper-stage and payload propulsion systems; probability of occurrence for each failure mode including method of derivation and a fault tree analysis if multiple components or subsystems are involved

c. Probability of stable flight and stability characteristics of prematurely separated and thrusting stage, stage and payload, and payload alone, both within and outside the sensible atmosphere; effects of structural confinement such as payload fairing on prematurely separated upper stage or payload

d. Risk Study: Results of the study shall include the impact probability for critical facilities and land areas that can be endangered by the payload or stage prior to orbital injection. Additional requirements will be established by Range Safety depending on the potential hazards associated with the payload or stage.

e. Residual Thrust Dispersion Analysis: The dispersion analysis is to show the extent to which the impact point(s) can deviate from nominal if the payload or stage separate prematurely and the propulsion system ignites. Computations are generally required from liftoff until upper stage fuel depletion or orbit insertion.

f. Intact Impact Analysis: Explosive effects of solid rocket and liquid motors upon ground impact. This analysis shall contain piece description, number of pieces, and range the explosion propels pieces from the motor impact point.

2.6.1.2 Nominal Trajectory

Position and velocity (X, Y, Z, ✠, ✡, ☪) as functions of time from liftoff until vehicle attains an altitude of 100,000 ft**. If position and velocity components are not available, ground range and altitude may be substituted for X, Y, Z, and the total earth-fixed velocity relative to the pad and the path angle may be substituted for ✠, ✡, ☪. The data should be provided in time increments no larger than five** seconds. If trajectory data cannot be provided, the steepness of the trajectory in the launch area should be compared with the trajectory from any prior similar operation.

2.6.1.3 Vehicle Maximum Turn Capabilities

The vehicle maximum turn capability describes the furthest distance the vehicle impact point can deviate from nominal if a malfunction should occur. See Appendix 2B for details.

2.6.1.4 Maps

a. A map showing the planned vacuum locus of impact points for the intended flight azimuth or azimuth sector. The vacuum impact point at times of discrete events; such as arming of engine cutoff circuits, ignition of upper stages, firing of retro-rockets, and the end of burns that occur prior to orbital injection shall be indicated.

b. A map showing the best estimates of mean impact points and the three-sigma drag-corrected impact dispersion area for each jettisoned body.

2.6.1.5 Orbit Parameters and Sequence of Events

The following data shall be provided for space vehicles only:

a. Apogee, perigee, period, and inclination of intended orbits

b. The approximate times from liftoff when engine cutoff circuits are armed, when upper stages will be cutoff by backup devices, and when control modes will be switched

2.6.2 Final Flight Data Package Requirements

These data are required in addition to the data requirements specified in paragraph 2.5.8.2.

a. Detailed information concerning the nature and purpose of the flight

b. A scaled diagram of the arrangement and dimensions of the missile or space vehicle

c. Approximate elapsed time from receipt of an FTS signal at the command antenna until FTS charges explode

2.6.2.1 Limits of a Useful Mission

The information requested in this paragraph applies to space operations only. It is used to establish guidelines or limits for land overflight prior to orbital injection. The permissible limits for overflight depend not only on this information, but also on estimated overflight hazards, the operational objectives potentially achievable, and the importance of these objectives. Since the derivation of the following items may be lengthy and costly, Range User best engineering estimates will be acceptable when a more exact study is not economically feasible. **NOTE:** A risk study (paragraph 2.5.6) shall be submitted for overflight conditions.

a. The launch azimuth limits for which the primary operation objectives can be met and for which a useful orbit can be attained

b. The operation objectives that will be met, or the extent to which the primary objectives will be degraded

c. Description of limiting orbit(s) (apogee, perigee, period, and inclination) as a function of overflight azimuth

d. The circumstances or types of malfunctions that can cause the vehicle to fly outside the three-sigma limits of normality but remain within the limits for which a useful orbit can be attained

e. The probability of occurrence of such malfunctions

f. A discussion on the effects of such malfunctions on the success of succeeding burns or stages

g. The most lofted and depressed trajectories for which the primary operation objective can be met and for which a useful orbit can be attained, giving the information requested in paragraphs 2.6.2.1.a through 2.6.2.1.f. In deriving these trajectories, only perturbations that result in deviations in the pitch plane should be considered. If these trajectories cannot be provided, the following may be substituted:

1. If the stage that normally achieves orbit does not contain an FTS, provide the upper and lower altitude limits at shutdown of the last sub-orbital stage if the succeeding stage is to attain a useful orbit.

2. If the stage that normally achieves orbit contains an FTS, provide the upper and lower altitude limits as the vacuum impact point reaches the continent to be overflown by the first orbital stage if this stage is to attain a useful orbit.

3. Provide the minimum impact range that the last suborbital stage must achieve if the succeeding stage is to attain a useful orbit and a minimum orbit (perigee of at least 70 miles).

2.6.2.2 Trajectories

This paragraph identifies the types of trajectories required for the following flight plans. All trajectories are to be developed using the procedures and format described in Appendix 2A.

a. Single Flight Azimuths. See Appendix 2A, Table 2A-1 (Items 1-8).

b. Variable Flight Azimuths. Space vehicle launches with variable flight azimuths shall provide a complete set of firing tables detailing launch times and flight azimuths for each day of the launch window. See Appendix 2A, Table 2A-2.

c. Multiple Liquid Propellant Engines Thrusting at Liftoff. For single or variable azimuth flight plans with launch vehicles having multiple liquid propellant engines that normally thrust at liftoff, the trajectories in Table 2A-3 of Appendix 2A are required for engine-out (not thrusting) conditions. The precise engine-out condition(s) shall be specified by Range Safety after the vehicle configuration is known.

2.6.2.3 Malfunction Turn Data

The turning capability of the vehicle velocity vector as a function of thrust vector offsets or other parameter characterizing the turn. See Appendix 2B.

2.6.2.4 Fragment Data

Effects of flight termination action and other potential modes of structural failure on each stage. See Appendix 2C.

2.6.2.5 Jettisoned Body Data

Nominal impact point, associated drag data, and impact dispersion data for each jettisoned body. See Appendix 2D.

2.6.2.6 Sequence of Events

Times from liftoff of discrete events such as ignition, cutoff, and separation of stages, firing of ullage rockets, jettisoning of components, firing of separation rockets, initiation and termination of various control and guidance modes, starting and ending of coast periods and control modes, arming of engine cutoff circuits, and settings for backup engine cutoff signals

2.6.2.7 Solid Propellant Characteristics

a. Burning rate of solid propellants (in/sec) as a function of pressure, including ambient atmospheric pressures

b. Percent propellant TNT equivalency for each stage as a function of relevant impact parameters such as weight of propellant, impact velocity, surface composition, and impact geometry

c. Stage ignition and burntime, propellant weight versus time, and propellant density

2.6.2.8 Acoustic Intensity Contours

a. Acoustic intensity contours above 85 dB at 10 dB intervals that are generated during launch of the vehicle

b. The predominant acoustical bands above 85 dB at distances of .5, 1, 2, and 3 nm surrounding the launch pad

2.6.2.9 High Q Flight Region

A statement indicating the flight time interval when the vehicle is experiencing the “high q” flight region. **NOTE:** This region is defined as the time during flight when the dynamic pressure causes vehicle aerodynamic breakup during a malfunction turn with the result of creating little or no crossrange displacement.

2.6.2.10 Orbital Parameters for Space Vehicles

a. Apogee, perigee, inclination, and period of orbits to be achieved; the time, altitude, latitude, and longitude of the submissile point for post-injection events such as ignition and cutoff of each stage, separation of payload, and reignition of upper stages

b. The state vector (position and velocity components) at the beginning and ending of each thrusting phase after initial orbit insertion

c. The state vector (position and velocity components) for any separated stage or component at the beginning of its final coast or free-flight phase

2.6.2.11 Air-Launched Vehicle Data

For air-launched ballistic and space vehicles, the data in Section 2.11 is required.

2.6.3 Sonic Boom Analysis Data

The following information may be required for a sonic boom hazard analysis:

2.6.3.1 Control Information

a. R - distance (ft) from vehicle where the Near Field Signature (NFS) is determined

b. LM - length (ft) of model of vehicle

c. LR - vehicle length (ft)

2.6.3.2 NFS Data with Exhaust Plume

a. θ - roll angle (deg)

b. M - mach number

c. N - number of points in NFS

d. X - vehicle station (ft) on model where pressure perturbation was measured

e. $\Delta P / P$ - pressure perturbation divided by ambient pressure

2.7 CRUISE MISSILES AND REMOTELY PILOTED VEHICLES SPECIFIC DATA REQUIREMENTS

The trajectory and performance data requirements in this section apply to cruise missiles, remotely piloted vehicles, or drone aircraft. In general, cruise missile operations involving intentional land overflight (except for launch and landing) will not be approved. In highly unusual situations where the operation objectives dictate otherwise and preliminary flight plan approval has been granted, the information requested in paragraph 2.7.2.1 will be used to establish guidelines or limits for land overflight. The permissible limits will depend not only on this information but also on estimates of overflight hazards, the operation objectives, and the importance of these objectives. The following items are required for each flight or group of similar flights and should be updated as vehicle configuration changes occur or revised information becomes available.

2.7.1 Preliminary Flight Data Package Requirements

These data are required in addition to requirements in paragraph 2.5.8.1.

a. Position and velocity (X, Y, Z, $\dot{X}$, $\dot{Y}$, $\dot{Z}$) as a function of time from launch until cruise altitude or a cruise condition is reached. If position and velocity components are not available, ground range and altitude may be substituted for X, Y, Z, and the total earth-fixed velocity relative to the pad and the path angle may be substituted for $\dot{X}$, $\dot{Y}$, $\dot{Z}$. The data are to be provided in time increments no larger than five seconds. If trajectory data cannot be provided, the steepness of the trajectory in the launch area should be compared with the trajectory from any prior similar operation.

b. Vehicle maximum turn capabilities. The maximum turn describes the furthest distance the vehicle impact point can deviate from nominal if a malfunction should occur. See Appendix 2B for details.

c. A map showing the expected flight path over the earth’s surface. Times are to be indicated at regular intervals along the path.

d. A graph showing an altitude profile correlated with the flight path. Times are to be indicated at regular intervals along the path.

e. A map showing the estimate of nominal impact points and three-sigma drag-corrected impact dispersion areas for each jettisoned body.

2.7.2 Final Flight Data Package Requirements

These data are required in addition to requirements in paragraph 2.5.8.2.

a. General information concerning the nature and purpose of the flight

b. A scaled diagram of the general arrangements and dimensions of the vehicle

c. Tracking aids, such as S or C band transponder and telemetry transmitter, in the vehicle that can be used for flight safety purposes; the stage or section where each is located

d. Trajectory deviations or other conditions beyond which the Range User is willing to accept flight termination action even though the vehicle has not reached a dangerous position or attitude

e. Approximate elapsed time from receipt of an FTS signal at the command antenna until FTS charges explode or recovery sequence is initiated

f. Graphs of fuel weight (lbs) vs time (sec or min)

g. Graphs of gross weight (lbs) vs time (sec or min)

h. Graph of maximum cruising speed (ft/sec) vs altitude (ft)

2.7.2.1 Land Overflight Data

a. The flight azimuth limits or the maximum deviations from the nominal flight path for which the primary operation objectives can be met

b. The flight azimuth limits or the maximum deviations from the nominal flight path for which a useful operation can be accomplished, even though the vehicle is outside the normal three-sigma limits

c. The operation objectives that will not be met or the extent to which primary objectives will be degraded if land overflight is not permitted when the missile is outside the three-sigma normal limits

d. Circumstances or types of malfunctions that can cause the missile to fly outside the three-sigma limits of normality but still accomplish useful objectives

e. The probability of occurrence of the malfunctions listed in response to paragraph 2.7.2.1.d. above

2.7.2.2 Trajectories

This paragraph identifies the types of trajectories required for the following flight plans. All trajectories are to be developed using the procedures and format described in Appendix 2A.

a. Single flight azimuths. See Appendix 2A, Table 2A-1.

b. Variable Flight Azimuths. Operations with variable flight azimuths shall provide a complete set of firing tables detailing launch times and flight azimuths for each day of the launch window. See Appendix 2A, Table 2A-2.

c. Multiple Liquid Propellant Engines Thrusting at Ignition. For single or variable azimuth flight plans with vehicles having multiple liquid propellant engines that normally thrust at liftoff, the trajectories in Table 2A-3 of Appendix 2A are required for engine-out (not thrusting) conditions. The precise engine-out condition(s) will be specified by Range Safety after the vehicle configuration is known.

2.7.2.3 Malfunction Turn Data

The turning capability of the vehicle velocity vector as a function of thrust vector offsets or other parameter characterizing the turn. See Appendix 2B.

2.7.2.4 Fragment Data

Effects of flight termination action and other potential modes of structural failure on each stage. See Appendix 2C.

2.7.2.5 Jettisoned Body Data

Nominal impact point, associated drag data, and impact dispersion data for each jettisoned body. See Appendix 2D.

2.7.2.6 Sequence of Events

Using the launch or drop time as the zero reference, time of discrete events such as ignition, cutoff, separation of booster stages, jettisoning of components, starting and ending of control modes, and initiation of recovery devices.

2.7.2.7 Solid Propellant Characteristics

a. Burning rate of solid propellants (in/sec) as a function of pressure, including ambient atmospheric pressures.

b. Percent propellant TNT equivalency for each stage as a function of relevant impact parameters such as weight of propellant, impact ve-locity, surface composition, and impact geometry.

c. Stage ignition and burntime, propellant weight versus time, and propellant density

2.7.2.8 Air-Launched Vehicle Data Requirements

For air-launched vehicles, the information in Section 2.11 is required.

2.8 SMALL UNGUIDED ROCKETS AND PROBE VEHICLES SPECIFIC DATA REQUIREMENTS

The trajectory and performance data requirements in this section apply to all small rockets. Although the term *small unguided rocket* is not precisely defined here, it generally refers to one and two-stage rockets having maximum impact ranges less than 100 nm Small rockets are not required to carry FTSs when dispersion analyses and control of launch conditions indicate that all vehicle components can be contained within predetermined safe areas. Unguided rockets of more than two stages or with impact ranges greater than 100 nm normally are required to carry an FTS. In this event, the data requirements specified in Section 2.6 for ballistic missiles and space vehicles will apply. The following vehicle related items are required for each rocket flight or group of similar flights and should be updated as vehicle configuration changes occur or revised information becomes available.

2.8.1 Preliminary Flight Data Package Requirements

These data are required in addition to requirements in paragraph 2.5.8.1.

a. Burn time of each stage

b. Graphs of impact range vs launch elevation angle for the planned elevation angle sector

c. Graphs of ground range vs altitude for the planned elevation angle sector

d. Proposed flight azimuth limits

e. Elevation angle limits

f. Summary of past vehicle performance giving number launched, launch location, number that performed normally and number that malfunctioned, behavior and impact location for those that malfunctioned, nature of malfunction and corrective action. This requirement can be met by submission of portions of the Reliability and Malfunction Analysis Data Requirements (paragraph 2.5.8.1.2.).

2.8.2 Final Flight Data Package Requirements

These data are required in addition to requirements in paragraph 2.5.8.2.

2.8.2.1 General Data

a. General information concerning the purpose and objectives of the operation, such as data to be obtained, number of launches planned, and a brief description of the payload, giving approximate weights

b. Scaled diagram of vehicle

c. Geodetic latitude and longitude of launch point or launcher

d. Desired launch azimuth and launch elevation angle. Give the variation in azimuth and elevation angles that are acceptable from the standpoint of the operation objectives. Indicate which of the operation objectives actually determine the acceptable limits for azimuth and elevation angle.

e. A brief description of the type of launcher; for example, zero length or short rail, travel distance of rocket to clear launcher, the amount of effective guidance, launcher adjustments available in quadrant elevation angle (QE) and azimuth, and the smallest increment for these adjustments

f. Total vehicle weight at liftoff

g. Total propellant weight in each stage at liftoff

h. Inert weight of each stage and separable component after burnout or jettison

2.8.2.2 Jettisoned Body Data

Nominal impact point, associated drag data, and impact dispersion data for each jettisoned body. See Appendix 2D.

2.8.2.3 Wind Effects Data

In most cases, wind is the largest independent factor causing displacement of unguided vehicle impact points. Accompanied by tabulations, charts, and a comprehensive discussion of their formulation, the following data are required to predict the magnitude and direction of this effect:

a. Ballistic wind-weighting factors vs altitude in feet. The effects of booster and first-stage wind drifts are of prime importance since the first-stage motor impact point is usually near the launch site. The wind-weighting factor shall be presented in percent of wind effect for specific wind altitude intervals or for specific altitude interval as a percentage of the total wind effect. The ballistic wind-weighting factors shall include the effects of both weather cocking and drift.

b. Change in the nominal impact point location due to missile weather cocking and drift as a result of ballistic winds (head, tail and cross; or resultant wind effect). The deviation is required in feet or nautical miles per foot per second of the wind. Since deviations vary significantly with a change in launch quadrant elevation angle (QE), values shall be supplied in a table of launcher QE vs unit wind effect. The table shall cover the range of elevation angles for which launches are to occur with an elevation angle interval no greater than 2 degrees and include plus and minus 12 degrees from the desired resultant QE up to a maximum launcher setting of 88 degrees.

c. Launcher adjustment curve or launcher tilt effect to correct the launcher in azimuth and elevation for wind effects. A discussion of methods to be employed in adjusting the launcher settings to compensate for winds is required. This data is required only if the Range User desires to adjust the launcher azimuth and elevation to correct for wind effects and shall be supplied for all desired resultant QEs. Wind compensation minimizes the area clearance problem by maintaining a constant impact point. A thorough description of the correction method and the expected accuracies to be achieved are required in addition to the proper curves and tabulation of data.

d. A graphical and tabular presentation of the impact point displacement due to earth rotation vs QE. Calculations for this information are based upon the latitude of the launcher and the desired launch azimuth. The table shall have a minimum interval of 2 degrees and include plus and minus 12 degrees from the desired resultant QE up to a maximum of 88 degrees.

e. When a computer program is used to perform the calculation required for adjustment of the launcher in QE and azimuth, the Range User shall include a discussion of the intended use of the program. If the Range User uses one of the computer programs available at the Range, Range Safety should be consulted to make sure that data requirements in paragraphs 2.8.2.3.a through 2.8.2.3.d above, are presented in a form compatible with the computer input requirements.

2.8.2.4 Analyses for Long Range Probes

All analyses for long-range probes (500 nm plus) shall be calculated using a rotating spherical or ellipsoidal gravity field. In contrast to the majority of probe vehicles, long-range probes normally require an FTS incorporated into the vehicle. The data requirements are the same as those specified in Section 2.6 for guided ballistic missiles. A risk study (paragraph 2.5.6) is required to evaluate requests to waive the requirement for an FTS on a long-range probe vehicle.

2.8.2.5 Launch Aircraft Data

For air-launched rockets or probes, the data items in section 2.11 are required.

2.8.2.6 Trajectory Requirements

See Appendix 2A.

2.8.2.7 Graphs

In addition to the tabular nominal trajectory data, graphs of the following shall be provided for each stage and payload weight.

a. Impact range vs launch elevation angle (ft or nm vs deg)

b. Apogee altitude vs launch elevation angle (ft vs deg)

c. Ground range vs altitude (ft or nm vs ft)

2.8.3 Statement of Vehicle Performance

In addition to the data requested in paragraph 2.5.9, the following data are required:

a. Vehicle type and number, launch location, operation number, payload type and weight

b. Actual launcher azimuth and elevation setting (deg)

c. For each stage and payload, the predicted range (nm) and azimuth (deg) from the launcher to the impact point based upon the predicted winds at time of launch

d. Actual range (nm) and azimuth (deg) from the launcher to the impact point for each stage and payload

e. Actual impact range (nm) for each stage and payload giving components measured along and perpendicular to the predicted impact azimuth. Where a stage is not tracked to impact, the impact point should be computed using the best estimates of the drag characteristics and of the winds at launch.

f. Predicted effective QE (deg) of trajectory for each stage *g*. Actual effective QE (deg) of trajectory for each stage

h. Predicted range (nm) and altitude (ft) of apogee for each stage

i. Actual range (nm) and altitude (ft) of apogee for each stage

j. A tabulation of the reduced wind data used in the launcher-setting calculations giving speed (ft/sec) and direction (deg) as a function of altitude (ft)

k. A reference list of all documents, graphs, and tabulations that were used in making the launcher setting calculations (wind-weighting curves, ballistic wind-weighting factors, and unit wind effect)

l. Description of the tracking data source

2.9 AEROSTAT AND BALLOON SPECIFIC DATA REQUIREMENTS

The trajectory and performance data requirements in this section apply to large unmanned, untethered, and tethered aerostats and balloons. They do not apply to small weather balloons and other such objects that are released routinely throughout the country and the world for scientific purposes.

2.9.1 Preliminary Flight Data Package Requirements

These data are required in addition to requirements in paragraph 2.5.8.1.

a. Description of the proposed flight plan giving particulars about the location and boundaries of the proposed test area, time sequence and description of significant events, flight duration, altitude, and speed limits

b. Method of control, including emergency control procedures

2.9.2 Final Flight Data Package Requirements

These data are required in addition to requirements in paragraph 2.5.8.2.

2.9.2.1 Untethered Aerostats/Balloons

Large unmanned and untethered aerostats and/or balloons flight tested on the Range shall carry an approved FTS capable of causing rapid deflation upon command. The following vehicle related items are required for each flight or group of similar flights. The data should be updated as vehicle configurations vary or revised information becomes available.

a. Detailed information concerning the purpose and objectives of the mission, data to be obtained, number of flights planned, proposed flight dates

b. A statement indicating whether the vehicle and proposed flights are similar to prior flights either on the Range or elsewhere

c. A description of the vehicle giving dimensions, component weights, materials, and characteristics of propulsion, control, and recovery systems including estimates of system reliability

d. Accuracy of guidance and control system in maintaining desired aerostat position

e. Description and location of FTS

f. Description and location of tracking aids

g. Wind restrictions for launch and flight

h. Description of proposed flight plan

1. Location of proposed test area

2. Graph of altitude (ft) vs time (min) from release until float altitude is reached

3. Total duration of flight

4. Graph of altitude (ft) vs time (min) for entire operation or indication of how altitude will be varied throughout flight

5. Maximum possible altitude without bursting

6. Maximum aerostat speed in still air as function of altitude

7. Location and size of impact dispersion areas for any bodies jettisoned during flight

8. Location and size of final impact dispersion area or intended recovery area

i. Coefficient of drag (C_d) vs Mach number giving reference area and weight for each jettisoned body and for the entire vehicle (or resulting components) after activation of the FTS. **NOTE:** The same data should also be provided for a normal recovery sequence if different from the above.

2.9.2.2 Tethered Aerostats/Balloons

Tethered aerostats/balloons shall carry an approved automatic FTS that will cause rapid deflation if the balloon escapes its mooring or the tether breaks. The following vehicle-related items are required for each flight or group of similar flights. The data should be updated as vehicle configurations vary or revised information becomes available.

a. Detailed information concerning the purpose and objectives of the mission, data to be obtained, number of flights planned, proposed flight dates *b*. Description and location of FTS

c. Description of mooring tethering system giving lengths and breaking strength of tether

d. Operational method of measuring tension in tether

e. Wind and weather restriction for launch and flight

f. Maximum float altitude

g. Planned and maximum duration of flight

2.10 PROJECTILE, TORPEDO, AIR-DROPPED BODY, AND DEVICE SPECIFIC DATA REQUIREMENTS

The data requirements in this section apply to projectiles and small devices that normally would not contain an FTS and that may or may not be propulsive.

2.10.1 Preliminary Flight Data Package Requirements

In addition to the data requested in paragraph 2.5.8.1, the following data are required:

a. Description of the proposed flight plan giving particulars about the location and boundaries of the proposed operation area, time sequence and description of significant events

b. Burn or thrust time of each thrusting item

c. Graphs of impact range (nm) vs launch-elevation angle (deg) for the planned elevation-angle sector or drop-altitude sector

d. Ground range (nm) vs altitude (ft) for the planned elevation-angle sector or drop-altitude sector

e. Nominal impact location in geodetic latitude (deg) and longitude (deg) for each jettisoned or impacting body

f. Estimates of the three-sigma dispersion area in downrange (ft or nm) and crossrange (ft or nm) measured from the nominal impact location

2.10.2 Final Flight Data Package Requirements

In addition to the data requested in paragraph 2.5.8.2. the following data are required:

a. Detailed information concerning the purpose of the operation, data to be obtained, description of objects, number of operations in the program, and proposed operation dates

b. Scaled diagram of vehicle

c. Latitude and longitude of the desired drop or launch point and the maximum region around the point where drop or launch could occur. **NOTE:** This information may be provided in distances downrange and crossrange relative to the expected drop point or by providing the geodetic latitude and longitude of the corners of the area.

d. Jettisoned Body Data. (See Appendix 2D.)

1. Latitude and longitude of the desired impact or target point

2. The three-sigma downrange and crossrange impact dispersions or circular error probability (CEP) of impact points for each impacting body. **NOTE:** This information may be provided in distances downrange and crossrange relative to the expected drop point or by providing the geodetic latitude and longitude of the corners of the area.

3. For air-dropped bodies, the effect of a three-sigma aircraft position and velocity error at drop

4. If the body descends on a parachute or other device, drag data before and after chute opening

e. For air-dropped bodies, the data items in the **Air-Launched Vehicle Specific Data Requirements** (Section 2.11) of this Chapter shall be provided.

f. The effect of head wind, tail wind, and cross wind on the impact point location in terms of displacement distance (ft or nm) per knot (or ft/sec) of wind

g. Trajectory Requirements. The following trajectory data items are required for each operation or group of similar operations.

1. A graph of the nominal trajectory, including a plot of altitude (ft) vs downrange distance (ft or nm); timing marks (sec), including the impact time, shall be indicated along the trajectory. **NOTE:** Separate graphs are required for each planned drop altitude or other condition.

2. The maximum horizontal distance (ft or nm) that can be traveled by the objects from the drop or launch point to impact

3. If the objects descend on a parachute, a plot of altitude (ft) vs range (ft or nm) for the case where the chute fails to open

2.11 AIR-LAUNCHED VEHICLE SPECIFIC DATA REQUIREMENTS

The data requirements in this section apply to all programs that use an aircraft as the originating platform for the operation.

2.11.1 General Data Requirements

a. General information concerning the nature and purpose of the flight

b. Specify minimum weather requirements for the operation.

c. Emergency Requirements. Specify special emergency requirements including:

1. Search and Rescue support requirements

2. Emergency Recovery Plan, including minimum field length(s)

3. Description of ditching characteristics, if known

4. Description of secondary communication procedures to be used in the event of primary communications failure

5. If structural flight and systems tests are to be conducted, any weather minimums and special requirements

2.11.2 Aircraft Data Requirements

a. Aircraft type (chase, tanker, etc.) and "N" or tail number and performance capability of aircraft, such as turn rate, climb rate, and velocity

b. For other than level flight launches, an additional statement describing how the aircraft path angle and launch azimuth are determined for vehicle release

c. Description of guidance system used and how ignition time and altitude are determined

2.11.3 Aircraft Flight Plan Data Requirements

a. Description of drop aircraft flight plan, such as aircraft flight azimuth (degrees true), speed (kts), altitude (ft), flight path angle (deg) of velocity vector relative to local horizontal at vehicle drop point; a map showing the flight path over the earth's surface with altitudes and speeds indicated at appropriate check points

b. The expected maximum region around the drop point, (a drop point envelope where the operation is conducted) provided as distances downrange, uprange, and crossrange relative to the expected drop point and perpendicular to the launch azimuth or by the geodetic latitude and longitude of the corners of the drop box

c. A definition and description of events occurring prior to vehicle release and to time of vehicle engine ignition

d. Predicted impacts of jettisoned hardware associated with the vehicle drop system and their impact dispersion

e. For ballistic air-dropped bodies, altitude of the aircraft, true air speed, and dive angle beginning 60 sec prior to drop and continuing through drop

2.11.4 Launched Vehicle Data Requirements

a. A nominal flight profile for each stage from launch to impact, showing altitude (ft) vs downrange (ft) is required. Profiles shall include parachute opening, parachute not opening, all unignited and non-separation conditions of the vehicle. Timing marks in seconds shall be indicated on the trajectory, as well as total time of flight for each object dropped.

b. The drop rate of launched vehicle and description of stabilizing system used

c. Method of ignition and position of the vehicle relative to the earth at ignition

2.11.5 Sonic Boom Data Requirements

In accordance with AFI 13-201, a sonic boom report may be required if supersonic flights are to be conducted. If a sonic boom report is required, the following information shall be provided for a sonic boom hazard analysis:

2.11.5.1 Control Information

a. R - distance (ft) from aircraft where NFS is determined

b. LM - length (ft) of model of vehicle

c. LR - vehicle length (ft)

2.11.5.2 NFS Data

a. θ - roll angle (deg)

b. M - Mach No

c. N - number of points in NFS

d. X - Aircraft station (ft) on model where pressure perturbation was measured

e. $\Delta P / P$ - pressure perturbation divided by ambient pressure

2.11.5.3 Flight Profile Data

a. Time (sec)

b. Vehicle altitude (ft) above reference spheroid *c*. Geodetic latitude (deg) of vehicle

d. Longitude (deg) of vehicle

e. Vehicle freestream Mach number

f. Vehicle flight path angle (deg) measured up from horizontal

g. Vehicle heading (deg) from true North

h. $\dot{M}$ - The time rate of change of Mach number (per sec)

i. Time rate of change of flight path angle (deg/sec)

j. Time rate of change of heading (deg/sec)

k. Roll angle (deg) from horizontal up to right wing as viewed from behind the vehicle.

2.12 COLLISION AVOIDANCE

a. The Collision Avoidance (COLA) program shall be used in the minus count to protect manned orbiting objects from collision with a launch vehicle or its jettisoned debris.

b. The COLA program shall compute the closest approach for all launch vehicles exhibiting the potential to collide with the defined orbiting objects.

c. COLA runs shall be scheduled in a letter from Flight Analysis to Range Scheduling.

d. COLA data shall be used to establish unsafe launch intervals based on a closest approach criteria of 200 km for manned objects.

e. COLA closure periods shall be designated for launch intervals whose closest approach distances are less than the above criteria.

f. A COLA closure period will result in a launch hold or may cause a launch scrub depending on closure interval and the remaining opportunities in the launch window.

2.13 45 SW RANGE SAFETY REQUIREMENTS FOR THE ER

NOTE 1: Similar requirements for 30 SW Range Safety are found in the 30 SW RSOR. **NOTE 2:** In this section, *Range Safety* refers to 45 SW/SEOE and SEOS only. Other 45th Space Wing Range Safety offices are specified, as required.

2.13.1 Pre-flight Planning Requirements

a. Pre-flight computations and plots shall be made at the Central Computer Complex (CCC), Range Operations Control Center (ROCC), and the Technical Laboratory Computer Facility (TLCF).

b. Requirements for computer support at the CCC/ROCC and TLCF shall be levied by Range Safety via Requests for Computer Services.

c. The appropriate ER agencies shall provide computational, plotting, and reproduction services for Range Safety planning and pre-flight requirements as follows:

1. Operating computing and plotting equipment at the CCC/ROCC and TLCF

2. Performing analytical studies, formulating mathematical models, and developing computer programs to meet specifications established by Range Safety

3. Maintaining, documenting, and operating the computer programs listed in the current Semiannual Computer Program Survey document

4. Processing magnetic tapes and providing computer listings and trajectory output files

5. Computing random and systematic errors for the instrumentation systems used for flight control. **NOTE**: Errors must be converted to appropriate statistical parameters to evaluate the magnitude of real-time present position and impact predictor errors throughout thrusting flight.

6. Calculating acquisition times, look angles, aspect angle, and signal strengths to arrive at tracking, telemetry, and command destruct expected coverage estimates

7. Maintaining the real-time impact prediction program and other related real-time and prelaunch programs

8. Evaluating time delays in the real-time program and in associated instrumentation systems

9. Providing miscellaneous reproduction and photographic services including the preparation of view graphs and briefing slides as required

2.13.2 Telemetry Data Requirements for Impact Prediction

a. If available, launch vehicle real-time telemetry guidance data shall be used to generate an impact point for the MFCO.

b. 45 LG shall provide 45 SW/SEOO and Range Safety with coverage periods for which this data is valid in the Committed Coverage Plan (CCP).

2.13.3 RSD Verification Test Requirements

a. In accordance with Operations Directive (OD) 16, Annex B, an RSD verification test shall be performed.

b. At least seven working days prior to each major vehicle launch, Range Safety shall provide the following RSD requirements to the range contractor for preparation of the Range Safety backgrounds:

1. Type, number, and scale factors of displays

2. Disk file locations for trajectories and destruct criteria

3. Other data needed to prepare the RSD background display tapes

c. At least five working days before launch, Range Safety shall forward additional data and details required to prepare RSD background display verification tapes.

d. The Range Technical Services Contractor (RTSC) prepares final display and verification tapes, reviews them for accuracy and completeness, and corrects obvious discrepancies before the scheduled verification date.

e. RSD verification shall be completed no later than F-4 days prior to launch.

f. After the RSD display tapes have been verified by Range Safety, no changes shall be made to the tapes or any interrelated real-time program if the change can affect the real-time RSD displays.

2.13.4 Requirements for Notice to Airmen and Mariners

a. By F-10 days, Range Safety shall provide 45 RANS with the areas hazardous to ships and aircraft for all normally jettisoned and impacting stages.

b. 45 RANS is responsible for disseminating the Notice to Airmen (NOTAM) and Notice to Mariners (NTM) to aircraft and shipping interests.

2.13.5 Range Safety Displays

a. Range Safety Trajectory Display System. A Trajectory Display System for unclassified video presentation of RSD displays is required in the Range Safety areas, PAFB, Building 423, Room C-301D.

b. Range Safety Video Displays. The following displays shall be transmitted to a multi-channel monitor located in the Range Safety area, PAFB Building 423, Room C-301D:

1. IIP

2. Unclassified presentation of the trajectory display (IIP) from L-10 min to orbital insertion or impact

3. Unclassified presentation of the vertical plane (VP) trajectory display from L-10 min

4. Display of the weather forecast channel, including audio, by L-60 min, or 5 min prior to the scheduled launch weather briefing, whichever is earliest

5. Display of unclassified surveillance control charts no later than L-90 min

6. Display of NASA Select, with audio, during Space Shuttle launches no later than L-120 min

2.13.6 Wind Data Requirements for Major Launches

a. For all major launches from CCAS and KSC, the RWO shall provide Range Safety with a forecast of launch winds on F-1 day, on launch day, and at other times during the launch when requested.

b. The following procedure shall be used in providing wind data to Range Safety:

1. Using the most current wind observations, the RWO shall provide forecasts at times specified in a Range Safety "Range Safety Wind Requirements" letter to the Meteorological Systems Office.

2. In developing wind forecasts, the latest available balloon data and met-rocket data shall be combined to produce the best possible estimate of T-0 winds. For manned launch vehicles, the rocketsonde data shall be no older than 72 hours. For unmanned launch vehicles, the rocketsonde data will be the latest available. The following procedure shall be used to produce the best possible estimate of T-0 winds for both manned and unmanned launch vehicles:

(*a*) If the balloon bursts between 90,000 and 150,000 ft, all the rawinsonde/windsonde data available shall be used. Appended to it shall be the latest rocketsonde data producing a wind speed and direction file at 1,000 ft increments to an altitude of 150,000 ft with the appropriate data headers.

(*b*) If the balloon bursts between 60,000 and 90,000 ft altitude, the rawinsonde/windsonde data shall have appended to it the most current available rawinsonde/windsonde data up to 90,000 ft altitude. Above 90,000 ft up to 150,000 ft altitude, the latest rocketsonde data shall be appended, producing a wind speed and direction file at 1,000 ft increments to an altitude of 150,000 ft with the appropriate data headers.

(*c*) If the balloon bursts before reaching 60,000 ft altitude and time is available, another windsonde shall be released and the data as in paragraphs 2.12.6.b.2 (a) and 2.12.6.b.2 (b) above shall be added. If time is not available, the data available from the aborted balloon shall be used. Appended to is shall be the most current rawinsonde/windsonde data up to 90,000 ft altitude. Above 90,000 ft up to 150,000 ft altitude the latest rocketsonde data shall be used to produce a wind speed and direction file at 1,000 ft increments to an altitude of 150,000 ft with the appropriate data headers.

3. For unmanned launch vehicles, statistical winds data are provided in the "Range Safety Wind Requirements" letter as a possible replacement for the latest available rocketsonde data. Range Safety will determine on F-1 and on launch days if the statistical winds will be used in lieu of the rocketsonde data. RTDR data reduction personnel will merge the statistical wind data with the rawinsonde/windsonde data per the instructions given above for rocketsonde data.

4. In general, the launch day balloon shall be released no earlier then L-8 h.

5. The duty meteorologist should make changes based on the measured winds to ensure the highest accuracy in forecasts.

c. Forecasts of resolved winds (2,000 ft increments) and unresolved winds (1,000 ft increments) for one or more specific azimuths shall be required up to 150,000 ft in altitude. **NOTE:** The sign convention shall be positive for head winds and negative for tail winds.

d. The data shall be made available to Range Safety as specified in the "Range Safety Wind Requirements" letter within two hours after balloon release.

e. After the wind forecast has been prepared, a Launch Weather Officer (LWO) shall discuss the degree of confidence in the predicted winds with Range Safety personnel. The likelihood of any changes in wind speed or direction before the launch and the magnitude of any such changes shall also be discussed. As a result of this briefing and prelaunch analysis, Range Safety shall determine whether additional wind observations and computer runs shall be required.

f. If the wind forecast should subsequently change because of launch delays or other circumstances, the meteorologist shall inform the MFCO and Range Safety representative immediately. Estimates of quantitative changes in wind speed and direction as a function of altitude shall be provided.

g. At L-60 min, the RWO shall provide a weather forecast briefing for the launch area using closed circuit television and direct line or network communications.

APPENDIX 2A
TRAJECTORY DATA

2A.1 INTRODUCTION

This appendix provides background information and details about Range Safety trajectory requirements. It is applicable to ballistic, space, cruise, remotely piloted, and small unguided vehicles. Trajectories are to be provided in accordance with EWR 127-1, Annex to Chapter 2, "Flight Trajectory and Data Manual." The trajectory and two printouts with a letter of transmittal are required.

2A.2 TRAJECTORY DETAILS

2A.2.1 The X, Y, Z, coordinates referred to in this Chapter shall be referenced to an orthogonal, earth-fixed, left-handed system with its origin at the launch point or at a point on the earth's surface above or below the launch point. The XY plane shall be tangent to the ellipsoidal earth at the origin, the positive X axis shall coincide with the launch azimuth, and the positive Z axis shall be directed away from the earth, and the Y axis shall be positive to the right looking downrange.

2A.2.2 Trajectory Data Item Requirements

The required trajectories from Table 2A-1 through Table 2A-3 shall be calculated using a six degree-of-freedom program. Table 2A-4 lists the data items to be provided for each required trajectory. The data items are required in 1 sec intervals.

a. Ballistic Missiles and Space Vehicles. All trajectories except the three-sigma launch area trajectories shall be provided from launch up to a point in flight where effective thrust of the final stage has terminated, or to thrust termination of that stage or burn that places the vehicle in orbit. The launch area trajectories are required from lift-off until the vehicle attains an altitude of 100,000****** ft.

b. Cruise Missiles and Remotely Piloted Vehicles. The data items are required in tabular form in one sec intervals for the first two****** minutes of flight, in 15-sec****** intervals from this point until the missile reaches cruise altitude, in one-minute****** intervals throughout the cruise phase until the terminal phase of flight is reached, and at 15-sec****** intervals thereafter until operation termination or impact. The time 0.0 sec shall correspond to first motion for pad-launched missiles and to the instant of drop for air launches.

c. Small Unguided Rocket or Probe Vehicle. Table 2A-4 (Items 5 - 13) lists the data items to be provided for each trajectory from launch until burnout of the final stage for each desired nominal quadrant elevation angle and payload weight. These items shall be provided in tabular form as a function of time with each column of the table containing only a single parameter. Time shall be given at even intervals, not to exceed one sec increments during thrusting flight, and for times corresponding to ignition, thrust termination or burnout, and separation of each stage. If stage burning times are less than four sec, time intervals should be reduced to 0.2 sec or less.

2A.2.3 Nominal (Reference) Trajectory

The nominal or reference trajectory is the trajectory that the vehicle would fly if all vehicle parameters were exactly as expected, if all vehicle systems performed exactly as planned, and there were no external perturbing influences.

2A.2.4 Three-Sigma Dispersed Trajectories

The three-sigma dispersed trajectories define the downrange and crossrange limits of normality for the vehicle instantaneous impact point (IIP) at any time after launch. The three-sigma trajectories should be computed using annual wind profiles unless the launch is to be conducted at a particular time of the year and only at that time. Care should be exercised in the selection of the cumulative percentage frequency of the wind profile used for the computation of these trajectories. Selecting a wind profile as severe as the worst wind conditions when a launch would be attempted is usually recommended. In critical instances, this has the disadvantage of limiting the allowable launch azimuth or reducing the allowable launch day winds in the flight safety restrictions for wind drift of vehicle fragments resulting from FTS action. The flight termination criteria, allows for as much vehicle deviation due to wind as shown in these trajectories, but does not account for wind conditions that exceed those used in these computations.

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Table 2A-1
Trajectory Types for Single Flight Azimuths

Item #	Program	Trajectory Type	Ref. Para.
1	All programs	Nominal or reference.	2A.2.3
2	Ballistic Missile and Space Vehicle	Three-sigma maximum-performance	2A.2.4.1
3		Three-sigma minimum-performance	2A.2.4.1
4		Three-sigma lateral left	2A.2.4.2
5		Three-sigma lateral right	2A.2.4.2
6		Three-sigma steep launch area	2A.2.4.3
7		Three-sigma lateral launch area	2A.2.4.3
8		Fuel-exhaustion.	2A.2.4.4
9	Cruise Missile and Remotely Piloted Vehicles	Three-sigma maximum-altitude. The maximum altitude deviations (ft) above nominal as a function of ground range from the launch or drop point may be substituted for Table 2A-4, Item 3.	2A.2.4.1 2A.2.4.1.1
10		Three-sigma minimum-altitude. The maximum altitude deviations (ft) below nominal as a function of ground range from the launch or drop point may be substituted for Table 2A-4, Item 3.	2A.2.4.1 2A.2.4.1.1
11		Three-sigma lateral. The maximum lateral deviations (ft or nm) from the nominal flight path as a function of ground range from the launch or drop point may be substituted for Table 2A-4, Item 3	2A.2.4.2 2A.2.4.2.4
12		Fuel-exhaustion. Table 2A-4, Items 3 and 4, are required from launch or drop until the vehicle reaches a steady-state cruise condition. The three-sigma high-performance trajectory should define the vehicle capability limits in climbing to maximum altitude at the maximum possible rate.	2A.2.4.4 2A.2.4.4.1

Table 2A-2
Trajectory Types for Variable Flight Azimuths

Item #	Trajectory Type	Ref. Para.
1	Nominal, reference, central, or middle trajectory.	2A.2.3
2	Extreme right-hand nominal or steepest nominal trajectory.	2A.2.3
3	Extreme left-hand nominal or shallowest nominal trajectory.	2A.2.3
4	Three-sigma maximum-performance trajectory for the centrally located flight azimuth	2A.2.4.1
5	Three-sigma minimum-performance trajectory for the centrally located flight azimuth	2A.2.4.1
6	Three-sigma lateral trajectories for the centrally located flight azimuth	2A.2.4.2
7	Three-sigma steep launch area	2A.2.4.3
8	Three-sigma lateral launch area	2A.2.4.3
9	Fuel-exhaustion	2A.2.4.4

Table 2A-3
Trajectory Types for Multiple Liquid Propellant Engines Thrusting at Liftoff

Item #	Trajectory Type	Ref. Para.
1	Three-sigma steep launch area trajectory with one or more engines not thrusting	2A.2.4.3
2	Three-sigma lateral launch area trajectory with one or more engines not thrusting	2A.2.4.3

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Table 2A-4
Trajectory Data Items

Item #	Data Item	Comments
1	A brief discussion of the parameters considered, their standard deviations, and all assumptions and procedures used in deriving each of the dispersed trajectories.	
2	A graph and tabular listing of the wind profiles used (wind magnitude and direction vs altitude)	The source of the wind profiles used in the computations shall be identified.
3	X, Y, Z vs Time (ft and sec)	Cruise Missile and Remotely Piloted Vehicles: Units are ft or nautical miles and sec or minutes. After the first 2** minutes of flight, with Range Safety approval, X,Y,Z, may be replaced by ground range along the earth's surface from launch point to sub-missile point vs time, altitude above earth's surface vs time, and cross range displacement from nominal vs time.
4	✠, ✡, ☪ vs time (ft/sec and sec)	Cruise Missile and Remotely Piloted Vehicles: Units are the nearest one-tenth ft/sec and sec or minutes. After the first 2** minutes of flight, with Range Safety approval, ✠, ✡, ☪ may be replaced by speed (ft/s) vs time and path angle (deg) of velocity vector relative to local horizontal vs time.
5	Speed vs. time (ft/sec and sec)	
6	Path angle of velocity vector relative to local horizontal vs time (deg and sec)	
7	Altitude above the sub-vehicle point on the reference spheroid vs time. (ft and sec)	
8	Total weight vs time. (lb and sec)	
9	Ground range along reference spheroid from the origin (launch point) to a point directly beneath the missile vs time (nm and sec)	For Small Unguided Rocket or Probe Vehicle: Ground range units are ft.
10	Thrust vs time (lb and sec)	
11	Instantaneous impact point data	Geodetic latitude, longitude, impact range (nm) and remaining flight time (sec) vs time (sec).
12	Launch azimuth	Degrees measured clockwise from true North.
13	The name, coordinates, and mean sea level elevation of the coordinate system origin (launch pad).	
14	Name of reference spheroid used in trajectory calculations.	

To generate a single composite three-sigma trajectory in terms of instantaneous impact range, the following procedure is suggested: **NOTE**: If the following procedure is not used, a description of the method used to generate the three-sigma trajectories is required.

Step 1: Identify individual parameters such as thrust, weight, specific impulse, and atmospheric density that significantly affect the performance of the vehicle instantaneous impact point (IIP). Estimate three-sigma dispersions for these parameters.

Step 2: Run a series of trajectory computations or simulations where three-sigma values of significant perturbing parameters are introduced one at a time. At a suitable number of time points, tabulate the IIP deviations from nominal that have been caused by perturbing each parameter.

Step 3: At each time point and direction, calculate the square root of the sum of the squares of all deviations to arrive at the three-sigma IIP deviations.

Step 4: By further trajectory computations or simulations, generate a thrusting flight trajectory (a three-sigma, no-wind trajectory) that matches as closely as possible the three-sigma deviations calculated in Step 3. This may be done by perturbing

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only a few key parameters at varying magnitudes throughout the run.

Step 5: Compute the required three-sigma trajectory using worst-case winds together with the parameter magnitudes used to calculate the three-sigma no-wind trajectory. The wind dispersed trajectories indicate vehicle performance deviations due to the effects of severe winds. This data should be supplied until the vehicle attains an altitude where there is essentially no wind effect. It is usually sufficient to use 100,000 ft as this altitude limit. Computations should not be limited to wind drift but include all wind effects.

2A.2.4.1 Three-Sigma Maximum and Minimum Performance Trajectories

The three-sigma maximum and three-sigma minimum-performance trajectories define at any time after launch the limits of normality as far as impact downrange is concerned. The three-sigma maximum-performance trajectory provides the maximum downrange distance of the vacuum instantaneous impact point (IIP) for any given time and the three-sigma minimum-performance trajectory provides the minimum downrange distance of the IIP for any time. In calculating these trajectories, head and tail-wind profiles should be used that represent the worst wind conditions for which a launch would be attempted. For any particular time after launch, approximately 99.73 percent of all normal vehicles (assuming a normal Gaussian distribution) that are subjected to the assumed wind will have impact ranges lying between the extremes achieved at that time by three-sigma maximum performance and three- sigma minimum-performance vehicles. Of the 0.27 percent of the normal vehicles that fall outside the three-sigma limits, approximately half would be short and half would be long. It is recognized that it may not be possible for a normally performing, fully guided vehicle to fly either the three-sigma maximum or minimum-performance trajectory as defined above. However, what is wanted is a single trajectory having an impact range at any time greater than the impact range of 99.865 percent of all normal vehicles, and a single trajectory with an impact range at any time less than the impact range of 99.865 percent of all normal vehicles. Any deviation outside of three-sigma limits indicates that the vehicle is probably behaving in an abnormal, though not necessarily dangerous, fashion. Those parameters having a significant effect upon impact range, such as thrust, specific impulse, weight, variation in firing times of different stages, and fuel flow rates, should be combined in the best considered fashion to produce the required results.

2A.2.4.1.1 Cruise Missiles and Remotely Piloted Vehicles. The three-sigma maximum and minimum-altitude trajectories define for any ground range the limits of normality as far as altitude is concerned. In other words, for any particular ground range approximately 99.73 percent of all normal vehicles (assuming a normal Gaussian distribution) will have altitudes between the extremes defined by three-sigma maximum altitude and three-sigma minimum-altitude trajectories. Any deviation outside these limits indicates that the vehicle is behaving in an abnormal, though not necessarily dangerous, fashion. However, the MFCO may destroy such a vehicle if it is approaching land or threatening to get outside or below the command destruct coverage area.

2A.2.4.2 Three-Sigma Lateral Trajectory Requirements.

2A.2.4.2.1 Definition. Three-sigma lateral trajectories define the crossrange limits of normality for the vacuum instantaneous impact point (IIP). Both a three-sigma left and a three-sigma right trajectory must be provided. These trajectories should be calculated using the worst lateral wind conditions for which a launch would be attempted. For any downrange distance, the IIP traces for 99.73 percent of all normal vehicles subjected to the assumed winds lie between the three-sigma lateral IIP traces. For variable azimuth launches, a three-sigma left trajectory for the smallest flight azimuth in the approved azimuth sector and a three-sigma right trajectory for the largest flight azimuth in the approved sector are required in addition to three-sigma lateral trajectories for a centrally located flight azimuth. Unless the procedure is invalid, the assumption will be made that the three-sigma left and right trajectories provided for the centrally located azimuth can be used to produce a reasonable approximation of the three-sigma left and right trajectories for other flight

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azimuths by reorienting the X and Y axis of the data. For example, if the three-sigma lateral trajectories have been computed for a central flight azimuth of 100 degrees, the three-sigma lateral trajectories for a 90 degrees flight azimuth will be determined simply by assuming that the X axis is 90 degrees instead of 100 degrees. If this assumption is not reasonable, additional trajectories shall be provided to define the extreme left and right lateral limits.

2A.2.4.2.2 Use. Three-sigma lateral trajectories are needed to determine whether a normal vehicle experiencing a three-sigma deviation will violate flight safety destruct criteria. They may also be used as guidelines by the MFCO in deciding whether a vehicle will be allowed to continue in flight or to over fly land. When used for comparison with the impact predictor destruct criteria, the vacuum IIP data are required. When used on the present-position display, values of X, Y, Z along the three-sigma lateral trajectories are required. The three-sigma lateral trajectories, as defined in paragraph 2A.2.4.2.1 in terms of IIP, may not provide three-sigma deviations of the lateral position Y as a function of X, although this is normally assumed to be the case. If this assumption is not valid, the Range User should also submit three-sigma trajectories that define the lateral limits of Y in terms of X.

2A.2.4.2.3 Calculation. In calculating a three-sigma lateral trajectory, those parameters having a significant effect on the lateral deviation of the IIP (or of the position Y in terms of X) should be combined in the best considered fashion to produce the required results. The procedures described in paragraphs 2A.2.4 and 2A.2.4.1 for calculating three-sigma maximum and minimum-performance trajectories is also suggested here.

2A.2.4.2.4 Cruise Missile and Remotely Piloted Vehicles. The three-sigma lateral trajectory defines the lateral limits within which 99.73 percent of all normal missiles are expected to remain. This trajectory should be calculated using the worst lateral wind condition for which a launching would be attempted. Since only one three-sigma lateral trajectory is requested, the assumption will be made that the three-sigma left and three-sigma right trajectories are symmetric about the nominal trajectory. If this assumption is not reasonable, then both three-sigma left and three-sigma right trajectories must be provided. A missile that deviates outside the three- sigma lateral limits is subject to possible destruction if it is approaching land or threatening to get outside or below the command destruct coverage area.

2A.2.4.3 Dispersed Launch Area Trajectories. If the dispersed launch area trajectories are computed as specified and the proposed flight plan is approved, the launch agency can be certain that a normal vehicle will not violate the safety destruct criteria in the launch area, irrespective of the actual winds existing at launch. Unfortunately, there is also a distinct disadvantage in using extreme winds to calculate the dispersed trajectories. To arrive at destruct lines that will not be violated by vehicles flying the extreme trajectories, the allowances made for wind effects in the destruct line computations must be kept small. This in turn means that wind restrictions must be imposed on launch day. The wind profile used in the destruct calculations may be much smaller than the extreme wind profiles used to calculate the dispersed trajectories. In general, the greater the wind profile used in calculating the dispersed launch area trajectories, the steeper the trajectories are; and the steeper the dispersed trajectories, the more severe the Range Safety wind restriction must be on launch day to have acceptable destruct criteria. Reducing the wind profile in calculating the dispersed trajectories lessens the probability of a hold due to wind, but increases the probability that a normal vehicle will fly outside the limits defined by the dispersed trajectories. This in turn increases the probability that a normal vehicle will be destroyed. For those vehicle flights for which severe launch area wind restrictions are required, it may be necessary for the Range User to supply dispersed launch area trajectories for two or three different wind profiles. By so doing, the probability of a safety hold due to wind is thus reduced.

2A.2.4.3.1 Three-Sigma Steep Launch Area Trajectory. The three-sigma steep launch area trajectory should maximize Z as a function of X', where the azimuth of the X' axis must be specified by Range Safety for each program or group of similar flights. The positive X' axis is directed

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downrange from the launch point directly away from the uprange impact limit line so the negative X' axis intersects the impact limit line at right angles. In calculating this trajectory a head wind (or tail wind) blowing toward (or away from) the impact limit line, that is, blowing from (or toward) the positive X' direction, should be used. This wind profile should represent the worst conditions for which a launch would be attempted. If other perturbing factors such as gyro drift or high thrust add significantly to the uprange deviations caused by wind, these factors should also be included in the calculations. The steep launch area trajectory is a three-sigma trajectory in that, for any X', the value of Z along the three-sigma steepest trajectory would be greater than the corresponding values of Z achieved by 99.865 percent of all normal missiles subjected to the assumed head wind.

2A.2.4.3.2 Three-Sigma Lateral Launch Area Trajectory. The three-sigma lateral launch area trajectory should maximize Z as a function of Y', where the azimuth of the Y' axis must be specified by the Flight Safety Analysis Section for each program or group of similar flights. When looking down-range, the negative Y' axis is laterally directed to the right with respect to the intended flight line, the actual direction being perpendicular to the lateral impact limit line being protected. In calculating this trajectory, a lateral wind blowing toward (or away from) the impact limit line, that is, blowing from (or toward) the positive Y' direction should be used. This wind profile should represent the worst conditions for which a launch would be attempted. Other perturbing factors that add significantly to the vehicle lateral movement, such as gyro drift, roll program error, and alignment errors, should also be included in the calculations. The lateral launch area trajectory is a three-sigma trajectory in that, for any Y', the value of Z along the three-sigma lateral launch area trajectory would be greater than the corresponding values of Z achieved by 99.865 percent of all normal missiles subjected to the assumed lateral wind.

2A.2.4.4 Fuel-Exhaustion Trajectory**.** For many flights, a programmed thrust termination may be scheduled well in advance of fuel exhaustion. To know whether a potential safety problem can arise if the vehicle should fail to cut off, trajectory data through fuel exhaustion are needed. For ballistic missile flights, the information should be provided only for the last stage in accordance with assumptions mutually agreed to by the User and Range Safety. For orbital flights the fuel exhaustion trajectory should be provided for the last suborbital stage. The requirement should be met by extending either the nominal or three-sigma maximum-performance trajectory through fuel exhaustion, depending on which produces a greater impact range.

2A.2.4.4.1 Cruise Missile and Remotely Piloted Vehicles. The three-sigma high performance trajectory should define the vehicle capability limits in climbing to maximum altitude at the maximum possible rate. It defines at any time after launch the limits of normality as far as impact range is concerned. The three-sigma high-performance trajectory provides the maximum downrange distance of the vacuum instantaneous impact point (IIP) for any given time. In calculating this trajectory, a tail-wind profile should be used that represents the worst wind conditions for which a launching would be attempted. For any particular time after launch, approximately 99.73 percent of all normal vehicles (assuming a normal Gaussian distribution) will have impact ranges less than the range achieved at that time by a three-sigma high performance mission.

APPENDIX 2B
MALFUNCTION TURN DATA

2B.1 INTRODUCTION

This appendix provides background information and details about Range Safety malfunction turn data requirements. It is applicable to ballistic, space, cruise, and remotely piloted vehicles. The turn data shall describe the turning capability of the vehicle velocity vector as a function of thrust vector offset or other parameters characterizing the turns. This information is used to determine how fast a vehicle or, more exactly, a vehicle impact point can deviate from the nominal if a malfunction occurs. Velocity vector turn data is required only for the thrusting periods from launch up to a point in flight where effective thrust of the final stage has terminated or to thrust termination of that stage or burn that places the vehicle in orbit

2B.2 TURN DEFINITIONS

yaw turn - the angle turned in the lateral direction by the total velocity vector, not the angle turned in the horizontal plane by the horizontal component

maximum turn capability - the envelope of the maximum-rate trim and all tumble velocity vector turn angle curves for a given malfunction time, irrespective of how unlikely this rate is to occur.

trim turn - a turn resulting from a malfunction that causes the launch vehicle thrust moment to balance the aerodynamic moment while imparting a constant rotation rate to the vehicle longitudinal axis. The maximum-rate trim turn is the trim turn made at or near the greatest angle of attack that can be maintained while the aerodynamic moment is just balanced by the thrust moment, whether the vehicle is stable or unstable.

tumble turn - the family of tumble turns that results if the airframe rotates in an uncontrolled fashion at various angular rates, each rate being brought about by a different, constant value of the thrust vector offset angle or constant value of another parameter that defines the tumble turn

90 degree option - the turn produced by directing and maintaining the vehicle thrust at about 90 degrees to the velocity vector without regard for how this situation can be brought about

2B.3 MALFUNCTION TURN COMPUTATION REQUIREMENTS

a. Turning information need be computed for the nominal or reference trajectory only.

b. In the various velocity vector turn computations, it should be assumed that the vehicle performance is normal up to the point of the malfunction that produces the turn.

c. The effects of gravity shall be omitted from the final turn data calculations.

d. If pitch and yaw turn angles are essentially the same except for the effects of gravity, the yaw turn angles may be determined from pitch calculations that, in effect, have had the gravity component subtracted out at each step in the computations

e. During the first 100****** sec of flight both pitch and yaw turns shall be provided. After 100****** sec, turns need be computed only in the yaw plane. *EXCEPTION: During the first 100** sec of flight, when neglecting gravity, if the pitch and yaw turns are the same, only the yaw turns are required.*

f. Malfunction turn data are required for malfunctions initiated at even 4****** sec intervals beginning 4****** sec after first motion continuing for the first 100****** sec of flight or through the first-stage thrusting phase and into the second-stage phase for at least one time point, and at even 8****** sec intervals thereafter.

g. One possible difficulty needs to be mentioned in connection with calculating tumble turns for aerodynamically unstable missiles. In the high aerodynamic region it often turns out that no matter how small the initial deflection of the rocket engine, the airframe tumbles through 180 deg or one-half cycle in less than the specified time period for which the calculations are to be carried out. In such a case, if the computation is carried out for the specified time period, part of the angle turned by the velocity vector during the first half cycle is then canceled out during the second half cycle of the turn. If only tumble turns were considered in such cases, the conclusion would be reached that the vehicle velocity vector can turn through a greater angle in a shorter time period than it can in a longer time period. This is an unacceptable conclusion from a safety view

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point. The envelope of the family of tumble turns must rise continuously throughout the specified malfunction time period. One generally acceptable way to satisfy this requirement is to compute tumble turn angles without considering aerodynamic forces. Although such a vacuum turn cannot actually be simulated in the atmosphere by means of a constant engine deflection, in all likelihood there is some particular intelligent behavior of the engine that can approximate the turn fairly closely. If, however, vacuum tumble turns are considered unrealistic and unjustifiable, other types of malfunctions must be considered.

h. The turn data shall be defined for a series of malfunction modes such as thrust vector offset. Turn data computations shall include a credible distribution (range) of parameter values to demonstrate the variation of the turn characteristics caused by each malfunction mode. If the turns can occur as a function of more than one malfunction mode (e.g., SRM thrust vector offset angle for thrust vector control failures and thrust dissipation time for SRM nozzle burn through), turn data are required for each mode. Where possible, the same set of malfunction modes shall be used for each turn initiation time.

2B.4 TURN TRAJECTORIES

Although velocity vector turning computations are not required for the three-sigma maximum and three-sigma minimum performance trajectories, a method for applying the turn angles to these trajectories must be provided. The trajectory data items of paragraph 2A.2.2 must also be applied for the trajectory used to start the turn computations, if this trajectory is not one of those provided in response to paragraph 2A.2.1 . Although desirable, this trajectory need not be submitted in the format described in EWR 127-1, Annex to Chapter 2, “Flight Trajectory and Data Manual.” A columnar or block printout is acceptable. In addition, a complete discussion is required of assumptions made, methods of calculation, and equations used in deriving the malfunction turns.

2B.5 DETERMINING TYPES OF TURNS TO SUBMIT

In determining the maximum turn capability of a vehicle, the usual procedure is for the Range User to consider both trim turns and tumble turns, in both the pitch and yaw planes. However, with Range Safety approval, the Range User may elect to calculate turn rates using the 90-degree option in lieu of trim and tumble turns. If the 90 degree option is ruled out, the criteria for each of the vehicle conditions listed in paragraphs 2B.5.2 through 2B.5.4 should be used to determine whether trim turns, tumble turns, or both should be provided at each turn initiation time.

2B.5.1 90-Degree Option. In some cases, Range Safety may accept turning angles or rates computed on the basis of the 90 degree assumption even though it is extremely unlikely for the missile to achieve these turn rates. This option is usually quite disadvantageous to the Range User, since larger turning angles (higher turn rates) lead to more restrictive destruct criteria. Such unduly restrictive criteria could necessitate the revision of a proposed flight plan that may otherwise have been allowed, or could result in somewhat earlier destruction of an erratic missile.

2B.5.2 Condition 1: For Vehicles Aerodynamically Unstable at All Angles of Attack. During that part of flight where the maximum trim angle of attack is small, it may be obvious that tumble turns lead to greater turning angles. If the maximum trim angle of attack is large, trim turns will in all probability lead to higher turning angles than tumble turns, and hence to more restrictive destruct criteria.

a. If the Range User can state that the probability of flying a trim turn even for a period of only a few seconds is virtually zero, only tumble turns are required.

b. If the Range User cannot so state, a series of trim turns (that includes the maximum-rate trim turn) and the family of tumble turns shall be provided.

2B.5.3 Condition 2: For Vehicles Stable at All Angles of Attack

a. If the vehicle is so stable that the maxi-mum thrust moment cannot produce tumbling, but produces a maximum-rate trim turn at some angle of attack less than 90 degrees, a series of trim turns that includes the maximum-rate trim turn shall be provided.

b. If the maximum thrust moment results in a maximum-rate trim turn at some angle of attack

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greater than 90 degrees, a series of trim turns shall be provided only for angles of attack up to and including 90 degrees

2B.5.4 Condition 3: For Vehicles Unstable at Low Angles of Attack but Stable at Some Higher Angle of Attack Region

a. If large engine deflections result in tumbling, whereas small engine deflections do not, a series of trim and tumble turns should be generated as prescribed in paragraph 2B.5.2 for aerodynamically unstable missiles. **NOTE:** The same difficulty discussed in paragraph 2B.3.e with tumble turns may arise here, namely, the envelope of the computed tumble turns may fail to rise continuously throughout the entire time period for which the calculations are to be carried out. In this event, either tumble-turn calculations neglecting aerodynamic forces or trim-turn calculations must be made as discussed in paragraph 2B.5.2.

b. If both large and small constant engine deflections result in tumbling, irrespective of how small the deflection might be, the turn data achieved at the stability angle of attack, assuming no upsetting thrust moment, are required in addition to the turn data achieved by a tumbling vehicle. **NOTE:** This situation arises because the stability at high angles of attack is insufficient to arrest the angular velocity that is built up during the initial part of a tumble turn where the vehicle is unstable. Although the missile cannot arrive at this stability angle of attack as a result of the constant engine deflection, there is some deflection behavior that will produce this result. If arriving at such a deflection program is too difficult or too time consuming, it may be assumed that the vehicle somehow instantaneously rotated to the trim angle of attack and stabilizes at this point. If so, tumble turn angles may be used in Range Safety destruct calculations during that part of flight for which the envelope rises continuously for the duration of the computation.

2B.6 TURN DURATION

The malfunction turn data (turn angle and velocity magnitude curves) are to be provided at one** sec intervals, for at least 12** sec into the turn and until one of the following two conditions are met. **NOTE:** Various time intervals or time delays must be considered, since the delays that are built into the range safety destruct calculations depend upon the accuracy, sensitivity, and type of presentation associated with a particular instrumentation system as well as missile characteristics.

a. The vehicle reaches a critical loading condition that will cause breakup.

b. The vehicle is tumbling so rapidly that the effective thrust acceleration is negligible; for example, the projected vacuum impact point is no longer moving significantly.

2B.7 TURN DATA FORMAT

Malfunction turn data shall be delivered in the form of graphs. Scale factors of plots must be selected so the plotting and reading accuracies do not degrade the basis accuracy of the data. In addition, tabular listings of the data used to generate the graphs are required in ASCII format files on floppy disks with corresponding hard copies.

a. Velocity Turn Angle Graphs. For turn angle graphs the ordinate represents the total angle turned by the velocity vector in degrees, and the abscissa the time duration of the turn in sec.

b. Velocity Magnitude Graphs. For velocity magnitude graphs the ordinate represents the magnitude of the velocity vector in ft per sec and the abscissa the time duration of the turn in sec.

2B.8 TURN DATA ITEMS

The following data items are required for each malfunction initiation time. The information that describes the turn is required at intervals of one sec or less.

a. Velocity Turn Angle. One graph is required for each malfunction mode at each initiation time. For tumble turns, each graph is to include the envelope of all tumble turns for all possible constant thrust vector offset angles (or other parameter). In this case, plots of the individual tumble turn curves that are used to define the envelope are required on the same sheet with the envelope. For trim turns, a series of trim turn curves for representative values of thrust vector offset (or other parameter) is required. The series of trim turn curves shall include the maximum-rate trim turn.

b. Velocity Magnitude. Either total velocity magnitude or incremental change in velocity magnitude from time of malfunction can be presented, although the incremental change in the velocity is desired. For each thrust vector offset angle (or other parameter), the point on the velocity graph

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corresponding to the point of tangency on the tumble turn-angle envelope shall be indicated. For tumble turns, velocity magnitudes are required in graphical form as a function of time for each thrust vector offset (or other parameter) used to define the tumble turn envelope.

c. Vehicle Orientation. If the vehicle has thrust augmenting rocket motors, then the vehicle attitude (in the form of the angular orientation of the vehicle longitudinal axis) as a function of time into the turn is required for each turn initiation time.

d. Onset Conditions. The vehicle state at the beginning of the turn, including the thrust, weight, and state vector (including velocity magnitude) shall be provided for each set of curves.

e. Breakup Information. The Range User must specify if the vehicle will remain intact throughout the turn. If the vehicle will breakup during a turn, then the point (time) for which vehicle breakup is expected to occur must be indicated. The time into the turn at which vehicle breakup would occur can be a specific value or a probability distribution for time to breakup.

f. Probability of Occurrence. The distribution for the probability of occurrence for the value of the parameter defining the turns (thrust vector offset, etc.) must be defined for each parameter (as a function of turn initiation time if the distribution varies with time). Also, information defining how the probability distribution was determined must be provided.

2B.9 VELOCITY VECTOR TURN DATA FOR CRUISE MISSILES AND REMOTELY PILOTED VEHICLES

a. From launch or drop until cruise altitude is reached, this information is required to provide a means of determining the maximum angle through which the missile velocity vector can turn in the event of a malfunction. The maximum angles turned for time intervals up to about 30****** sec in duration are required. (The actual times will depend on the delays included in the FTS as well as other factors). Both pitch and yaw turns should be investigated and the larger presented. It should be assumed that the missile has followed the nominal trajectory up to the point of malfunction that produces the maximum-rate trim turn. Thereafter, it should be assumed that the missile is trimmed to the maximum air load that the structure can stand, or that the missile is flying out of control in an attitude that produces maximum lateral acceleration (for example, a near ninety degree bank with a maximum pitch turn). During the launch phase, the missile may not be able to fly for 30****** sec under these extreme conditions. In this event, it should be assumed that the missile is turning at the maximum rate for which these flight conditions can be maintained for required time duration. A complete discussion of the methods used in the calculations must be provided. This discussion should include assumptions made, types of malfunctions considered, forces producing turns, equations used, and sample computations.

b. During the cruise phase, the maximum turn capability of the velocity vector as a function of altitude is required. Rates should be based on normal missile weights and the expected cruising speeds at each altitude. For this phase of flight, the data may be expressed in the form of maximum lateral accelerations, if desired. A complete discussion similar to that requested for paragraph 2B.9.a is required. Also required are the maximum turn capability that the guidance system and the autopilot can command during the cruise phase.

c. A cruise missile may be boosted from the launch pad by separable rockets or by a booster motor that is an integral part of the missile. While the booster motor is thrusting, the missile may perform more as a ballistic missile or space vehicle than as a cruise missile. In such cases, maximum turning capability data during the boost phase will be required as specified in paragraph 2B.5 rather than as specified in paragraph 2B.9.a. For each missile program Range Safety will indicate which procedures are to be used in computing malfunction turn data during the boost phase.

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FRAGMENT DATA

2C.1 INTRODUCTION

Fragment listings and characteristics for all potential modes of vehicle breakup are required. At a minimum, the following modes of vehicle breakup shall be considered: (1) breakup due to FTS activation, (2) breakup due to an explosion, and (3) breakup due to aerodynamic loads, inertial loads, and atmospheric reentry heating. Fragment data is required up to thrust termination of the last stage that carries a destruct system. All fragments shall be included; however, similar fragments can be accounted for in fragment groups.

2C.2 DESCRIBING FRAGMENT GROUPS

A fragment group is one or more fragments whose characteristics are similar enough to allow all the fragments to be described by a single "average" set of characteristics. The following information is provided to aid in determining fragment groups:

a. Fragment type: All fragments must be of the same type (for example solid propellant, explosive, or inert), including whether or not propellant fragments are burning following breakup.

b. Ballistic coefficient (beta): The maximum beta in the group should be no more than about a factor of three times the minimum (except for very low beta fragments where betas ranging from near zero to about 3 psf can be grouped together).

c. Weight: If the fragments contain propellant that is burning during free fall the maximum weight of propellant in a fragment group should be no more than a factor of 1.2 times the minimum weight of propellant. The fragments included in a group should be such that the kinetic energies (*KE*) based on terminal velocity ($KE = 13 \times W \times beta$, ft-lbf) are within the following guidelines:

- Fragments having *KE* < 35 are grouped.
- Fragments having 35 < *KE* < 100 are grouped.
- Fragments having 100 < *KE* < 6,200 should be grouped so that the maximum fragment *KE* is no more than about three times the minimum.
- Fragments having 6,200 < *KE* < 33,670 should be grouped so that the maximum fragment *KE* is no more than about three times the minimum.
- Fragments having 33,670 < *KE* < 74,000 should be grouped so that the maximum fragment *KE* is no more than about three times the minimum.
- Fragments having 74,000 < *KE* < 1,616,000 should be grouped so that the maximum fragment *KE* is no more than about three times the minimum.
- Fragments having *KE* > 1,616,000 are grouped.

d. Velocity perturbation: The maximum expected destruct explosion or pressure rupture induced velocity in the group should be no more than a factor of 1.2 times the minimum induced velocity.

e. Projected area: For explosive fragments, the range of projected areas should be controlled by requiring that the maximum value of the weight of propellant at impact is no more than a factor of two times the minimum (however, if the propellant is burning during free fall the factor is 1.2). There is no limit on the range of projected areas for inert fragments.

2C.3 FRAGMENT DATA ITEMS

This paragraph provides a description of the data items required for each fragment or fragment group for each potential mode of vehicle breakup. The variation of the fragment characteristics with flight time shall be defined. Normally this is accomplished by specifying multiple fragment lists, each of which is applicable over a specified period of flight.

a. That fragment that, in the absence of winds, is expected to travel a maximum distance, and that fragment(s) that, in the absence of winds, is expected to travel a minimum distance shall be included.

b. Fragment group name

c. Number of fragments

d. General description(s) of fragments such as part/component, shape, dimensions, figure

e. Breakup Altitude. For breakup due to atmospheric reentry, the altitude at which breakup is expected to occur shall be provided.

f. Ballistic Coefficient (beta). Nominal, plus three-sigma, and minus three-sigma values (psf) for each fragment or group; including graphs of the coefficient of drag (C_d) versus Mach number for the nominal and three-sigma beta variations for each fragment or group. Each graph shall be labeled with the shape represented by the curve and reference area used to develop the curve. A C_d vs Mach curve for axial, transverse, and tumble orientations (when applicable) shall be provided for fragments not expected to stabilize during free-fall

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conditions. For fragments that may stabilize during free-fall, C_d vs Mach curves should be provided for the stability angle of attack. If the angle of attack where the fragment stabilizes is other than zero degrees, both the coefficient of lift (C_L) vs Mach number and the C_d vs Mach number curves should be provided. If available, equations for C_d vs Mach curves should be provided. The difficulty of estimating drag coefficient curves and weights for vehicle pieces is fully realized. If this cannot be done satisfactorily, an estimate of the subsonic and supersonic W/C_dA for each major piece may be provided instead. In either case, three-sigma tolerance limits shall be included for the drag coefficients for the maximum and minimum-distance pieces.

g. Weight per fragment. Include the possible three-sigma weight (lb) variation for the fragment or group. NOTE: The fragment data must approximately add up to the total weight of inert material in the vehicle plus the weight of contained liquid propellants and solid propellant that is not consumed in the initial breakup and/or conflagration.

h. Projected area per fragment (ft^2). Include the axial, transverse, and tumbling area for the fragment or group. This information is not required for those fragment groups classed as uncontained propellant fragments (as described below).

i. Estimates of the maximum incremental velocities (ft/sec) imparted to the vehicle pieces due to FTS activation, explosive and/or overpressure loads at breakup. The velocity is normally assumed to be Maxwellian distributed with the specified maximum value equal to the 97th percentile. If the distribution is known to be significantly different than the Maxwellian, the correct distribution is required (including if the specified value should be interpreted as a fixed value with no uncertainty).

j. Fragment group type:

Type 1 = inert fragments; for example, no volatile type material that could be burning or could explode

Type 2 = uncontained solid propellant fragments; for example, solid propellant exposed directly to the atmosphere and will not explode upon impact

Type 3 = contained propellant fragments; for example, propellant that is enclosed in a container, such as a motor case or pressure vessel, and will not explode upon impact

Type 4 = contained explosive propellant fragments; for example, propellant that is enclosed in a container, such as motor case or pressure vessel, and will explode upon impact

Type 5 = uncontained explosive solid propellant fragments; for example, solid propellant exposed directly to the atmosphere and will explode upon impact

k. Casualty area per fragment (ft^2). The casualty area per fragment shall be based on a fragment falling vertically at impact, and should reflect the credible fragment orientation giving the maximum projected area.

l. Vehicle stage where fragment group originated

m For those fragment groups defined as uncontained propellant fragments, contained propellant fragments, and explosive fragments, an indication as to whether or not the propellant fragments are burning during free fall.

n. For those fragment groups defined as contained propellant fragments, explosive or non-explosive, the initial weight of contained propellant (lb) and the consumption rate during free fall (lb per sec). The initial weight of the propellant in a contained propellant fragment is the weight of the propellant before any of the propellant is consumed by normal vehicle operation.

o. Diffusion and dispersion of any fragments containing toxic or radioactive materials and the radiation and exposure characteristics

2C.4 RESIDUAL THRUST DISPERSION

If an upper stage can be ignited as a result of FTS activation on a lower stage, sufficient information is required to evaluate the effects and duration of thrust, and the maximum deviation of the impact point that can be brought about by this thrust. The explosion effects on remaining fuels, pressurized tanks, and remaining stages are required, particularly with respect to ignition or detonation of upper stages if destruct action is taken during the burning period of a lower stage. For each thrusting or non-thrusting stage having residual thrust capability following FTS activation provide either the total residual impulse (lb-sec) imparted after

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"arm" and "destruct," or the full-residual thrust (lb-f) versus time (s). Otherwise, a detailed analysis that clearly shows the stages are not capable of thrusting after FTS activation is required.

APPENDIX 2D
JETTISONED BODY DATA

2D.1 GENERAL DATA REQUIREMENTS

The following data shall be provided for each jettisoned body:

a. The nominal impact point. The nominal impact point (or aiming point) for each jettisoned body shall be given in terms of geodetic latitude and longitude in decimal degrees, and range (nm) from the pad. Computations shall be made for an ellipsoidal rotating earth taking into account drag and, if applicable, lift.

b. The number of fragments resulting from a specific scheduled jettison. If the jettisoned body is expected to break up during reentry, an estimate of the number of pieces, their approximate weights, cross-sectional areas, ballistic coefficients and their impact ranges are required.

c. Jettison flight time (sec), total weight (lbs) jettisoned and weight per fragment (lbs), reference area per fragment (ft^2), and the best estimate of C_d vs Mach number (preferred) or subsonic and supersonic W/C_dA for each stage or piece. The C_d vs Mach number data are to be provided in graphical and tabular format for the nominal, minus three-sigma and plus three-sigma drag coefficients and shall cover the range of possible Mach numbers from zero to the maximum values expected during free fall. Also indicate whether bodies are stable and, if so, at what angles of attack. For pieces that can possibly stabilize during free flight, drag coefficient curves shall be provided for the stability angle of attack. If the stability angle of attack is other than zero degrees, both coefficient of lift (C_L) vs Mach number and C_d vs Mach number curves shall be provided. State briefly how drag curves were determined.

d. The three-sigma uprange-downrange (nm) and crossrange (nm) impact dispersions and the azimuth orientation of the dispersion major axis (degrees clockwise from true north), assuming a normally functioning vehicle. Three-sigma wind effects acting upon the descending body or pieces must be included in the dispersion area. A brief discussion of the method used to determine dispersions is also required. The magnitude of the wind contribution in the total dispersions is required.

e. Impact ballistic coefficient (psf).

f. Maximum possible impact range of each impacting stage or reentry vehicle for a missile burning to fuel exhaustion.

2D.2 REENTRY VEHICLE DATA

The items below are required either in records 23, 24, and 25 of the trajectory or with general vehicle data:

a. Type of reentry vehicle (RV) (ablation or heat sink) and ablation tables when applicable. The ablation table is a listing of Mach number or altitude vs the ratio W/W_o, where W equals the instantaneous RV weight during reentry and W_o equals the vehicle weight before ablation.

b. The RV weight before ablation

c. A table of RV drag coefficient versus Mach number of altitude

d. RV aerodynamic reference area associated with the drag coefficients

2D.3 SMALL UNGUIDED ROCKETS OR PROBE VEHICLES

Three-sigma range and cross-range dispersions are required for each stage, separable fragment or component, and payload. Since the magnitude of these dispersions may determine whether a destruct system deviation or waiver will be granted or the extent to which shipping must be clear of impact areas, a careful analysis is essential. The following factors should be considered in determining three-sigma impact dispersions about predicted impact points: Variation in thrust, error in drag estimates, thrust misalignment, fin and body misalignment, variation in weight, variation in ignition times of stages, impulse errors, tip-off and separation perturbations, errors in wind velocity measurements, error in launcher setting, and other significant perturbing influences. The three-sigma variation in each factor shall be provided in tabular format in addition to the extent to which each factor displaces the impact point of each stage in the downrange and crossrange directions. The total impact dispersion is then computed by a statistical combination of the individual displacements. A brief discussion of the assumptions made, method of analysis, and method of computation is required. The extent to which the three-sigma impact dispersion areas change with quadrant elevation angle is also required.