Module Purpose: Scoping & ConOps

♦ To understand the importance of defining a mission or project’s scope.

♦ To explain the contents of scope, including needs, goals, objectives, assumptions, authority and responsibility, constraints, and concept of operations.

♦ To understand the importance of developing a mission concept of operations (ConOps).

♦ To describe the information contained in a ConOps and show examples.
**Defining Scope**

- The first step in building a strong foundation for writing good requirements is defining the scope.
- What’s involved in defining the scope:
  - Defining the needs, goals, and objectives
  - Identifying stakeholders
  - Developing operational concepts
  - Understanding constraints
- Become familiar with parent system-of-interest documents. Examples:
  - *Presidential Directive* (for highest level systems)
  - *Announcement of Opportunities* contain need statements
  - *Proposals* contain goals and objectives
- “The beginning is the most important part of the work.”
  - Plato, 4th Century BC

**Scope Dimensions**

- **Need**
  - Explains why the project is developing this system from the stakeholders' point of view

- **Goals**
  - Broad, fundamental aim you expect to accomplish to fulfill need

- **Objectives**
  - Initiatives that implement the goal.
  - What is the minimum that the stakeholders expect from the system for it to be successful?

- **Assumptions**
  - Examples:
    - Level of technology
    - Partnerships
    - Extensibility to other missions

- **Mission**
  - Defining and restricting the missions will aid in identifying requirements

- **Constraints**
  - External items that cannot be controlled and that must be met, which are identified while defining the scope

- **Authority and Responsibility**
  - Who has authority for aspects of the system development?

- **Operational Concepts**
  - Imagine the operation of the future system and document the steps of how the end-to-end system will be used

- **Budgets**
  - Schedules
**Apollo Program Scope Example**

- **Need:** Counter Soviet military threat.
- **Goal:** Demonstrate American technological superiority.
- **Objective:** Make a decisive move in the conquest of space.
- **Mission or business case:** Transport a man to the moon, and return him safely.
- **Operational Concept:** Launch crew, lunar lander, and return vehicle on multistage rocket into trajectory for moon. Crew will leave return vehicle in lunar orbit while they take lunar lander to the moon surface. Crew will return to lunar orbit and rendezvous with return vehicle. Crew in return vehicle will land in ocean.
- **Assumptions:** All technology needs are achievable.
- **Constraints:** Do it within this decade. Use American-made components.
- **Authority and Responsibility:** NASA has the responsibility to carry out the mission.

**Crew Exploration Vehicle Scope Example**

- **Need:** Provide crewed access to space once the Shuttle is retired.
- **Goal:** Make access to space safer and cheaper than current system.
- **Objective:** Provide access to space and Earth re-entry for missions to ISS, Moon and Mars.
- **Mission or business case:** Support for all human space flight missions post Shuttle.
- **Operational Concept:** Launch...Rendezvous...Docking...Transfer...Re-entry...
- **Assumptions:** Separation of crew and cargo for launch phase.
- **Constraints:** Deliver an operational vehicle no later than 2014; Minimize the gap with Shuttle retirement in 2010.
- **Authority and Responsibility:** CEV is to be managed by NASA with no international involvement.
- **Drivers:** Presidential vision for space exploration in 2004; safety concerns with Shuttle post Columbia accident.
**Apophis Scope Example**  
*(UT ASE 387P.2 Students, 2007)*

- **Need:** Understand threat posed by any NEO (Near Earth Object)
- **Goal:** Accurately predict Earth impact probability of any NEO
- **Objective:** Track any NEO requiring higher precision in calculation of impact probability
- **Mission:** Tag and track the asteroid Apophis

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**Apophis Scope Example, cont.**  
*(UT ASE 387P.2 Students, 2007)*

- **Operational Concept:**
  - Launch (Satellite payload including orbiter and optional lander component)
  - Pre-transfer (Earth orbit or direct transfer)
  - Transfer
  - Encounter (Fly-by and/or rendezvous and/or orbit)
  - Tag (Impact optional lander and/or remain in orbit)
  - Track (Ground post-processing operations)
- **Assumptions:** All technology requirements are available. Joint mission is conducted between responsible parties.
- **Constraints:** Mission complete before 2017. Greater than 10% confidence that Apophis will hit the 2029 keyhole. Meet targeted budget.
- **Authority and Responsibility:**
  - Mission Design: Our team
  - Implementation (hardware manufacture, operations): NASA and/or ESA and/or other concerned government space agencies
Concept of Operations (ConOps)

- **What is a ConOps?** A description of how the system will be operated during the mission phases in order to meet stakeholder expectations.

- **Importance of a ConOps:**
  - Provides an operational perspective
  - Stimulates requirements development related to the user
  - Reveals requirements and design functions as different "use cases" are considered (e.g., Shuttle)
  - Serves as the basis for key operations documents later

- **Mars Phoenix mission example:**
  - ConOps leads to addition of the requirement to "view" the descent, and landing phase during the mission. This requires a camera in a specific location that can withstand the entry profile. Under nominal operations, the camera may not be required.
  - "Beginning just after the aeroshell is jettisoned at an altitude of about 5 miles, the Mars Descent Imager (MARDI) will acquire a series of wide-angle, color images of the landing site all the way down to the surface."

Typical Information Contained in ConOps

- Description of the major phases
- Operational scenarios and/or design reference missions (DRMs)
  - For human exploration missions, multiple DRMs make up a ConOps
- Operation timelines
- End-to-end communications strategy
- Command and data architecture
- Operational facilities (e.g., mission control, science data center)
- Integrated logistics support (resupply, maintenance, and assembly)
- Critical events

Design Reference Mission: A use-case scenario which stress all of the system's capabilities to a significant extent and which all design alternatives will have to be able to accomplish. The purpose of such missions is to keep the design space open.
ConOps - Start with Pictures
Operational Scenario and Timeline

Source: Texas 2-Step Mission, Project Plan, 2007
ConOps - Example Timeline

more detailed, later in mission design


ConOps - Example Design Reference Mission

ConOps - End-to-End Communications Strategy

Scoping Exercise Leads to Organized Requirements

Why is access to space required?

Science goals → Mission Statement

- Clear, specific statement describing goals & objectives
- Does not necessarily require justification
- Should not, in general, specify requirements

Mission Goals & Requirements

- Clear, specific statements describing mission products & methods
- Define minimum success and preferred goals
- In general, should drive (but not specify) system requirements

System / Operational Requirements

- Subsystem specifications
- CONOPs plan

Space Systems Engineering: Scoping & ConOps Module

Pause and Learn Opportunity

View the James Webb Space Telescope (JWST) Mission Operations Concept Document (.pdf)

It is 256 pages; viewing the table of contents alone demonstrates the key elements, such as the science goals, the astronomer’s (i.e., customer’s) view, the basic system architecture, operations strategies, and more.

Module Summary: Scoping & ConOps

♦ The first step in understanding the mission at hand is defining the scope, where scope is a definition of what is germane to your project.
♦ The scope content involves
  • Defining the needs, goals, and objectives
  • Identifying stakeholders
  • Developing operational concepts
  • Understanding the constraints
♦ A thorough scoping effort leads to organized and informed mission and system requirements.
♦ A concept of operations (conops) is a description of how the system will be operated during the mission phases in order to meet stakeholder expectations.
♦ A concept of operations can include many aspects of operations, such as a timeline, a communications strategy, varying operational scenarios, etc.
Backup Slides for Scoping and ConOps Module

Initial Mission Flow Diagram

Total mission duration: 902-945 days
Time on Mars surface: 500-600 days
TEI: Multi-burn injection used at perigee to inject vehicles toward Mars.
Scope Elements - Definitions

Need
- Drives everything else
- Related to your strategic plan or business plan
- NOT a definition of the system or solution
- Explains why the project is developing this system from the stakeholders' point of view
- Does not change much during the life of the project

Goals
- A goal is a broad, fundamental aim that your organization expects to accomplish to fulfill its need.

Objectives
- Expand on how you will meet the goals.
- Initiatives that implement the goals
- Also specify the success criteria - what is the minimum that the stakeholders expect from the system for it to be successful?

Mission
- The business case for why product is needed.
- Defining and restricting the missions will aid in identifying requirements.

Constraints
- External items that cannot be controlled and that must be met, which are identified while defining the scope.
- Often defined in terms of schedule and budgets.

Authority and Responsibility
- Who has authority for aspects of the system development? (e.g., government center, contractor, customer)

Assumptions
- As identified by stakeholders, as part of the scope elements listed above

Operational Concepts
- A step-by-step description of how the proposed system should operate and interact with its users and its external interfaces (e.g., other systems).
- Don't forget to include the stakeholders' perspectives, such as astronauts
- Imagine the operation of the future system and document the steps of how the end-to-end system will be used.
- Describes, at a high level, the nominal and off-nominal scenarios
Additional Information for Defining Stakeholder Expectations


Driven by science strategic plans or from a Presidential Directive?

How the mission must be operated in order to achieve mission objectives.

Dependent upon ConOps - operational environment, orbit, mission duration, etc.

Trade Studies Identified as a Result of Apophis Scoping & ConOps Exercise

- **Epoch**: required tracking time, transfer time, mission duration
- **Launch vehicle**: payload capacity, propulsion, current availability
- **Power**: radioisotope thermoelectric generator, solar panel, propulsion
- **Journey**: earth orbit, direct transfer
- **Encounter**: impact, rendezvous, fly-by, trailing
- **Tagging**: reflector, beacon, transponder, orbiter
- **Tracking**: instrument precision, blackout, signal relay
- **Additional Operations**: map asteroid, composition study, other science operations
Typical Operational Phases for a NASA Mission

♦ Integration & Test (I&T) Operations
  • Project I&T — During the latter period of project I&T, the system is tested by performing operational simulations during functional and environmental testing. The simulations typically exercise the end-to-end command and data system to provide a complete verifications of system functionality and performance against simulated project operational scenarios.
  • Launch Integration — The launch integration phase repeats I&T operational and functional verification in the launch integrated configuration.

♦ Launch Operations
  • Launch — Launch operation occur during the launch countdown, launch ascent, and orbit injection. Critical event telemetry is an important driver during this phase.
  • Deployment — Following orbit injection, spacecraft deployment operations reconfigure the spacecraft to its orbital configuration. Typically, critical events covering solar array, antenna and other deployments, and orbit trim maneuvers occur during this phase.
  • In-orbit checkout — In-orbit checkout performs is used to perform a verification that all systems are healthy. This is followed by on-orbit alignment, calibration, and parameterization of the flight systems to prepare for science operations.

♦ Science Operations
  • The majority of the operational lifetime is used to perform science operations.

♦ Safe Hold Operations
  • As a result of on-board fault detection, or by ground command, the spacecraft may transition to a safe hold mode. This mode is designed to maintain the spacecraft in a power positive, thermally stable state until the fault is resolved and science operations can resume.

♦ Anomaly Resolution and Maintenance Operations
  • Anomaly resolution and maintenance operations often requires the support of personnel beyond those used for science operations.

♦ Disposal Operations
  • Disposal operations occur at the end of project life. These operations are used to either provide a controlled reentry of the spacecraft, or a repositioning of the spacecraft to a disposal orbit. In the latter case, the dissipation of stored fuel and electrical energy is required.