Module Purpose: Functional Analysis

♦ Define functional analysis and place it in context within system development.

♦ Describe the activities and value of functional analysis.

♦ Describe, and illustrate with examples, two tools of functional analysis - Functional Flow Block Diagrams and Time Line Analysis.
Functional Analysis - Definitions

♦ Functional analysis is the systematic process of identifying, describing, and relating the functions a system must perform in order to be successful. *It does not address how these functions will be performed.*

♦ In the early phases of the project life cycle, functional analysis deals with:
  • The top-level functions that need to be performed by the system;
  • Where these functions need to be performed;
  • How often they need to be performed; and
  • Under what operational concept and environmental conditions.

♦ In later phases, functional analysis proceeds to lower levels of the system decomposition to define the system functional design and interfaces.
Why Do Functional Analysis?

♦ To determine all functionality needed to meet requirements.
♦ To identify profitable trade studies.
♦ In describing what must be done and not how to do it, we define requirements independent of implementation. This leaves the implementation trade spaces unbiased.

But “…decomposition cannot be found in a book or dictated by the stakeholders; the decomposition is a product of the engineers of the system and is part of the architecture design process that is attempting to solve the design problem established by the requirements. The decomposition can be carried out as deeply as needed to define the transformations that the system must be able to perform.”

Buede, D.M. *The Engineering Design of Systems: Methods and Models*
Functional Analysis Flow and Some of Its Tools

- Develop Functional Architecture
- Functional Flow Analysis
- Functional Interface Analysis
- Timeline Analysis

Functional Architecture

Functions Dictionary

N² Diagrams

Functional Flow Block Diagrams

Timelines
**Functional Analysis Tools**

♦ **Functional Architecture**
  • Top-down definition of system functions.
  • Dictionary describing each function.

♦ **Functional flow block diagrams (FFBDs)**
  • Used to show the sequence of all functions to be accomplished by a system.

♦ **N-squared Diagrams**
  • Used to develop data, function or hardware interfaces.
  • {See lecture module on N-squared diagrams and interfaces}

♦ **Timelines**
  • Adds consideration of functional durations.
  • Used to support the development of requirements for operations, test and maintenance functions.
Functional Decomposition of a NASA Space Science Mission

Get There
- Escape Earth's Gravity Well
- Transfer to specified location(s)
- Achieve specified proximity, orientation to target(s) for specified time interval(s)

Obtain Data
- Collect data in specified priority, sequence, with specified quality, quantity
- Process data to specified level
- Return data to Earth

Generate Results
- Process data to specified level
- Validate data
- Distribute data to users (science team)
- Obtain ancillary or secondary data from other sources
- Interpret and analyze data

Communicate Results
- To sponsors
- To science community
- To public

Archive Results

Terminate Mission
- Operate within Safety Limits

Applicable to:
- Flybys
- Orbiters (Earth and Planetary)
- In situ missions
- Constellations
- Heliocentric observers
- Sample return missions
- Occultation experiments
Exploration Systems Engineering: Functional Analysis Module

Functional Architecture of a Planetary Defense Program

Planetary Defense

1. Detect Threat
   - 1.1 Coordinate Assets
   - 1.2 Monitor Sky
   - 1.3 Confirm Sighting(s)
   - 1.4 Determine Composition
   - 1.5 Determine Size
   - 1.6 Determine Velocity
   - 1.7 Determine Orbital Elements
   - 1.8 Run Simulation(s)
   - 1.9 Establish Level of Threat
   - 1.10 Decide on Action

2. Eliminate Threat
   - 2.1 Track Target
   - 2.2 Run Simulation(s)
   - 2.3 Prepare Delivery System
   - 2.4 Prepare “Payload”
   - 2.5 Implement Response

3. Re-evaluate Threat
   - 3.1 Monitor Impact
   - 3.2 Ref. Detect Threat
   - 3.3 Confirm Success/Failure
A primary functional analysis technique is the Functional Flow Block Diagram (FFBD).

**Purpose**: to show the sequential relationship of all functions that must be accomplished by a system.

Each function (represented by a block) is identified and described in terms of *inputs, outputs, and interfaces* from *top down* so that sub-functions are recognized as part of larger functional areas.

Some functions may be performed in *parallel*, or *alternate paths* may be taken.

Functions are arranged in a *logical sequence* so that any specified operational use of the system can be traced in an end-to-end path.

The FFBD network shows the logical sequence of “*what*” must happen, and *does not assume a particular answer to “how” a function will be performed.*
1. Detect Threat

1.1 Coordinate Assets

1.2 Monitor Sky

1.3 Confirm Sighting(s)

1.4 Determine Composition

1.5 Determine Size

1.6 Determine Velocity

1.7 Determine Orbital Elements

1.8 Run Simulation(s)

1.9 Establish Level of Threat

1.10 Decide on Action

Ref. 3. Reevaluate Threat (a)

Ref. 3. Reevaluate Threat (b)

Ref. 2. Eliminate Threat
Planetary Defense Level 1 Functional Flow
Block Diagram For Threat Elimination

2. Eliminate Threat

- 2.1 Track Target
- 2.2 Run Simulation
- 2.3 Prepare Delivery System
- 2.4 Prepare “Payload”
- 2.5 Implement Response

Ref. 1. Detect Threat
Ref. 3. Reevaluate Threat

or

Ref. 3. Reevaluate Threat
3. Reevaluate Threat

Ref. 2. Eliminate Threat

Monitor Impact

Ref. 2. Detect Threat (b)

Confirm Success or Failure

Ref. Detect Threat (a)

Ref. Eliminate Threat

Success

or

Failure
FFBD - Example for a Shuttle-Based Radar Mapping Mission

TOP LEVEL

1.0 Ascent Into Orbit Injection
2.0 Check Out and Deploy
3.0 Transfer to OPS Orbit
4.0 Perform Mission Operations
5.0 Contingency Operations
6.0 Transfer to STS Orbit
7.0 Retrieve Spacecraft
8.0 Reenter and Land

SECOND LEVEL

(3.0) Ref. Transfer to OPS Orbit
4.1 Provide Electric Power
4.2 Provide Attitude Stabilization
4.3 Provide Thermal Control

4.4 Provide Orbit Main
4.5 Receive Command
4.7 Store/Process Command
4.8 Acquire Payload Data
4.9 Acquire Subsystem Status Data
4.10 Transmit Payload & Subsystem Data
4.11 Transmit Subsystem Data

THIRD LEVEL

(4.7) Ref. Store/Process Command
4.8.1 Compute TDRS Pointing Vector
4.8.2 Slew to and Track TDRS
4.8.3 Radar to Standby
4.8.4 Compute LOS Pointing Vector
4.8.5 Slew S/C to LOS Vector
4.8.6 Command ERP PW Radar On
4.8.7 Process Receiving Signal and Format
4.8.8 Radar to Standby
4.8.9 Radar Off

(4.10) Ref. Transmit Payload & Subsystem Data
Although the FFBD network shows the logical sequence of “what” must happen, it does not ascribe a time duration to functions or between functions.

To understand time-critical requirements, a Time Line Analysis (TLA) is used. A TLA can be applied to such diverse operational functions as spacecraft command sequencing and launch vehicle processing.

TLA defines concurrency, overlapping, and sequential relationships of functions.

TLA is used to identify specific time-related design requirements.
Example shows the time required to perform function 3.1. Its sub-functions are presented on a bar chart showing how the timelines relate. Note: function numbers match the FFBD.
Pause and Learn Opportunity

Discuss James Webb Space Telescope (JWST) Functional Flow Block Diagram Examples using the following document:

JWST _FFBD_rev2.ppt

The examples show the various functions to be performed according to mission operational phase and in what particular sequence.
Module Summary: Functional Analysis

♦ Functional analysis is a system development tool used to capture required system functions.

♦ Functional analysis also supports functional decomposition - the process of describing the sub-functions that are necessary for each function.

♦ Functional Flow Block Diagrams (FFBDs) are graphical tools used to capture the functional sequence and functional hierarchy of a system.

♦ Time-Line Analysis (TLA) is a tool used to capture the duration, and sequence of system functions. TLA can be used in conjunction with FFBDs.

♦ Functional analysis is implementation independent. In other words, all functions are describes in terms of what must be done (and sometimes how well) not how it will be done. This independence ensures that when subsequent trade studies choose how functions will be performed they will be unbiased.
Backup Slides
for Functional Analysis Module
Functional Analysis Has Iterations with Both Requirements and Design

- **Requirements Analysis**
  - Understand the requirements and how they affect the way in which the system must function.

- **Design Loop**
  - Identify a feasible solution that functions in a way that meets the requirements.

- **Verification Loop**
  - Show that the synthesized design meets all requirements.

- **Functional Analysis**
  - Measure progress and effectiveness; assess alternatives; manage configuration, interfaces, data products and program risk.

- **Systems Analysis Optimization & Control**
FFBDs are made up of functional blocks each of which represents a definite, finite, discrete action to be accomplished. The functional architecture is developed using a series of leveled diagrams to show the functional decomposition and display the functions in their logical, sequential relationship. A consistent numbering scheme is used to label the blocks. The numbers establish identification and relationships that carry through all the diagrams and facilitate traceability from the lower levels to the top level. Each block in the first/top level diagram can be expanded to a series of functions in the second level diagram, and so on (see example, next slide). Lines connecting functions indicate function flow and not lapsed time or intermediate activity. Diagrams are laid out so that the flow direction is generally from left to right. Arrows are often used to indicate functional flows. The diagrams show both input (Transfer To OPS Orbit) and output (Transfer To STS Orbit), thus facilitating the definition of interfaces and control process.

Each diagram contains a reference to other functional diagrams to facilitate movement between pages of the diagrams. Gates are used: “AND”, “OR”, “Go/noGo”. A circle is used to denote a summing gate and is used when AND/OR is present. “AND” is used to indicate parallel functions and all conditions must be satisfied to proceed (i.e., concurrency). “OR” is used to indicate that alternative paths can be satisfied to proceed (i.e., selection). “G” and “bar G” are used to denote “go” and “no go” conditions. These symbols are placed adjacent to lines leaving a particular function to indicate alternative paths.
Basic Functional Timeline Example