LaACES Student Ballooning Course

System Design

Project Management Unit #2

What is system design?

- High level design identifying the system processes, functional components and their interfaces
- Derived from system requirements
- Provides an overview of the project
  - Define the components that are needed
  - Establish how components "communicate" with other components
  - Determine how to modularize the project into discrete work packages
  - Identify critical interfaces that must be well defined
- Used to provide initial cost, schedule & resource estimates
- Usually little or few implementation details
  - As system design is refined, and lower level subsystems are included, implementation issues may need to be addressed

System design steps

- Define project goal and objectives
- Develop the project system requirements
- Identify the major system components that satisfy the system requirements
- Identify the major system interfaces
- Refine the system design
  - Define subsystems making up each component
  - Specify interfaces between subsystems
- Establish management controls for the system interfaces

Project goal and objectives

- The goal specifies the overall purpose of the project
  - Defines what one wishes to accomplish as a result of the project
- Objectives are discrete intended accomplishments during and resulting from the project
  - *Science objectives* describe the specific scientific results expected from the project
  - *Technical objectives* describe the specific technical accomplishments expected during the project
- Together the project goal and objectives define and constrain the project scope
  - Leads to defining the system requirements

System requirements

- A document listing the constraints imposed upon and the results necessary from the project
  – The project goal as well as the scientific and technical objectives should be reflected in the system requirements
- Time spent on detailing the system requirements is worthwhile
  – A greater understanding of what is required facilitates design and implementation and improves the chances of success
- Initially focus on developing the high level scientific and technical requirements
  – Based upon current science knowledge, what is to be measured with what resolution and accuracy?
  – What constraints impose what technical limitations on your design?

Initial System Design

- Development of the initial system design can, at times, go hand-in-hand with refinement of the system requirements
  - Functions needed to satisfy the science requirements define the initial system
- For example, to perform any science measurement
  - You will need a sensor (detector system)
  - You will need to power the sensor (power system)
  - You will need to read data from the sensor (data acquisition system)
  - You will need to store the data (data archive system)
  - You will need to control the sensor, readout, storage (control system)
  - You will need to analyze the data (ground data system)
- These functions will also need to have a set of requirements specified
  - For example, the power system will need to supply volts & milliamps to the sensor, data acquisition, archive and control systems

LaACES Student Ballooning Course

Traceability Matrix

- Shows the relationship between requirements and the components that satisfy these requirements
  - Commonly used in software engineering, but has application to hardware as well
  - Used to assure that the system design properly addresses the project needs and does not incorporate any unnecessary components
- Format of the matrix can vary widely but generally includes the following for each requirement
  - Identification number
  - Description of the requirement
  - Description of the component that satisfies the requirement
  - Description of test that verifies the components meets the requirement
- One example is provided by the U.S. Department of Energy, Requirements Traceability Matrix Template

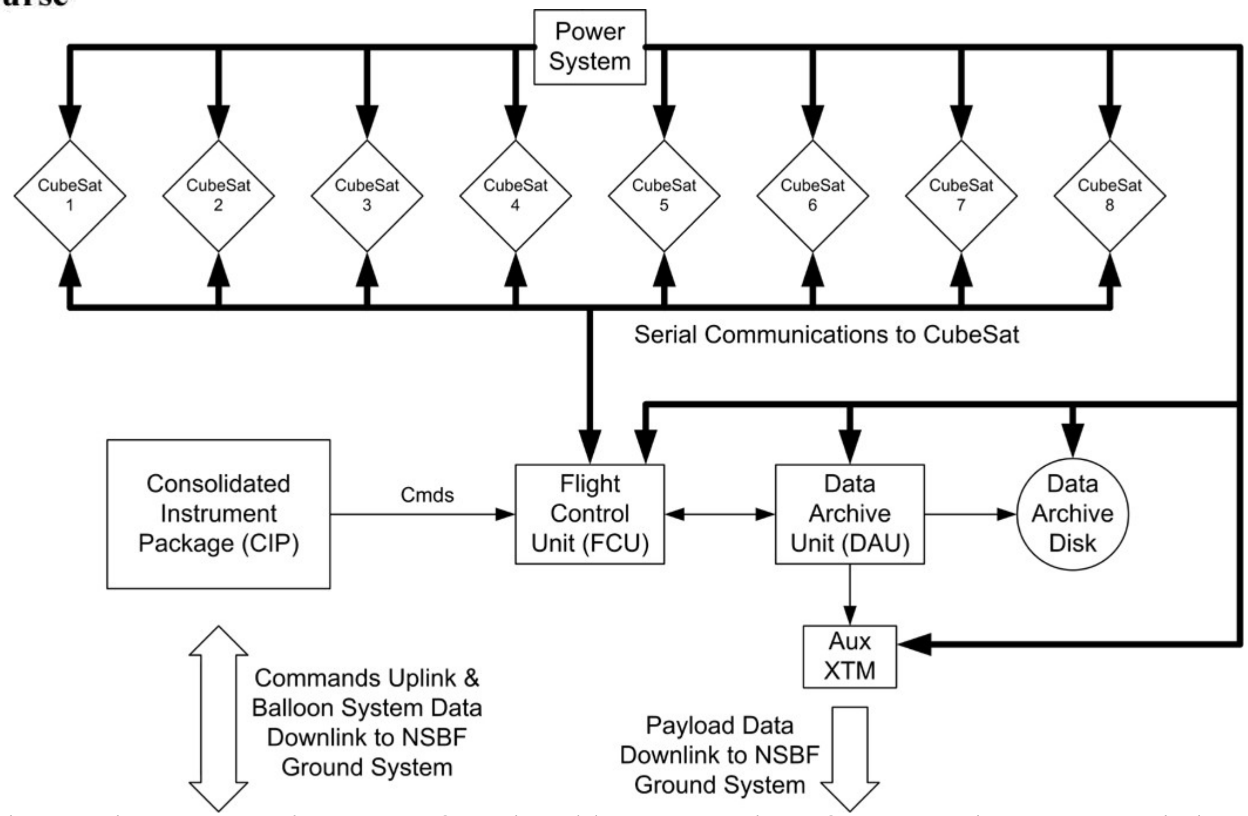
LaACES Student Ballooning Course

Major System Interfaces

- An interface describes the linkage between two functions or processes
- Neglecting how your systems fit together can lead to disaster
  - NASA Mars Climate Orbiter failed in 1999 because ground systems used "English" units while the flight systems used "Metric" units!
- There are multiple types of interfaces
  - **Mechanical:** How systems physically fit together
  - **Power:** What voltage and current flows between the systems
  - **Electronic:** The characteristics of electrical signals between systems
  - **Data:** Format and content of information transferred between systems
  - **Thermal:** How does heat flow between systems
  - **Software:** How modules communicate with other modules or hardware
- The type and characteristics of all interfaces need to be identified and defined

LaACES Student Ballooning Course

System Level Drawing Example



- High level overview of a balloon platform that could carry eight student built payloads
  - Primary subsystems are identified
  - Directionality and content of major interfaces are identified

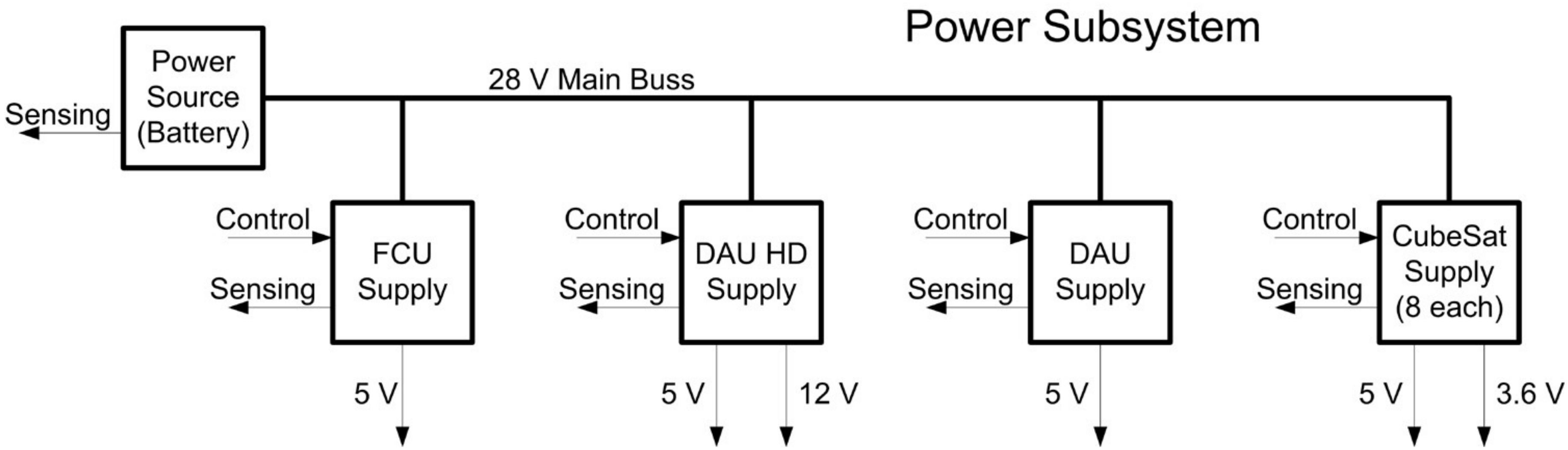
LaACES Student Ballooning Course

Refining the System Design

- After the major systems and interfaces are identified the subsystems are described
  - Each major function is composed of multiple activities, processes or modules each with a specific function of its own
- For example, the Power System in the previous slide has the following subsystems
  - Power source that supplies the energy for the entire platform
  - Separate supplies to convert the source power to the proper volts and amps required by the FCU, DAU, DAU Disk, Aux XTM and Cubesats
- Each of the subsystems has interfaces that need specification
  - How many of what kind of interface do the subsystems have?
  - Is the interface to another subsystem or another system?
  - What is the content of the interface?
- Traceability matrix should include these new subsystems

LaACES Student Ballooning Course

Subsystem Level Example



- Subsystem design provides additional details
  - Major functional components are identified and expressed
  - Shows that system requirements are satisfied
  - Most important interface details are revealed
- Still little hardware or implementation dependence

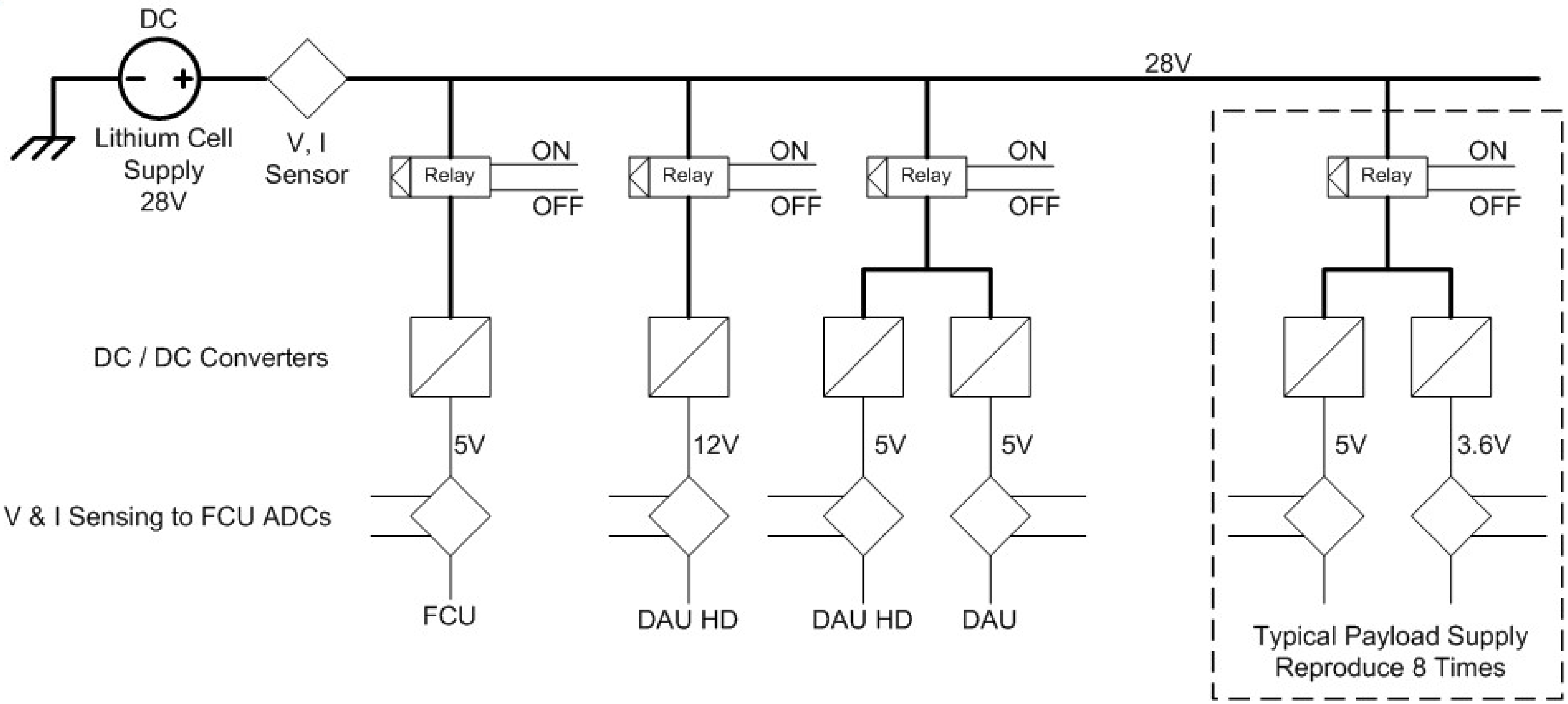
LaACES Student Ballooning Course

Moving to Design Specifics

- The system design refinement process continues by specifying the subsystems of the subsystems
- For example, the FCU supply in the power system might include the following sub- subsystems
  - A relay to turn the supply on / off by computer control
  - A DC / DC converter to provide the required voltage from the source power
  - An inline sensor so that volts and amps can be monitored in real-time by the computer
- With enough iterations the system design can evolve into an actual implementation
  - Actual components to use in the design start becoming apparent
  - Interfaces become very specific and well defined

LaACES Student Ballooning Course

Refined Subsystem Example



- Implementation and hardware details are starting to appear
- Interfaces are close to being fully defined
- Next step would be full hardware and interface specification

Controlling Interfaces

- Critical interfaces need to closely monitored by use of an Interface Control Document (ICD)
  - Written description of the interface that is modified only under specific, previously defined conditions and is used by team personnel for implementation
- Not all interfaces need to be controlled, but an ICD can be helpful during system design
  - Written specification of the interface
  - Obtain agreement between stakeholders on the interface characteristics
- Controlled ICDs should be used to help manage potential risks
  - When an interface error or mismatch could result in project failure
  - When stakeholders implementing the interface ends are separated in either geographic distance or time

References

- Managing Requirements Website, Ludwig Consulting Services, LLC, http://www.jiludwig.com/
- U.S. Department of Energy, Office of the Chief Information Officer, Systems Engineering / Project Management website http://cio.doe.gov/ITReform/sqse/project_management.htm
- U.S. Department of Energy, Office of the Chief Information Officer, Systems Engineering Publications and Templates http://cio.doe.gov/ITReform/sqse/publications.htm