Gateway To Space

ASEN 1400 / ASTR 2500

Class #26

T+17
Today:

- Announcements
- One Minute Reports
- Guest Lecture
Announcements:

- Grades posted by Monday - Delayed

- HW #9 Due Today
One Minute Report Questions:

https://youtu.be/vmYPGsD2IrU
Final Semester Team Evaluations...

- Due May 3rd (last class)
- Make sure your name is on the form

1 Star
Final Semester Team Evaluations...

- Team of six has **1200 points** (seven has 1400)

Total = **1200 points**
Final Semester Team Evaluations…

- Say not everyone is pulling their weight

Total = 1200 points
Final Semester Team Evaluations...

- I take everyone’s scores and do the math, taking into account how self scoring compares to team score for you.
Announcements:

- Expo this Saturday

EXPO AGENDA

7:00AM .................................................. ITLL OPENS (NO CONSTRUCTION!)
7:30-8:45AM ........................................... PROJECT SETUP AND REGISTRATION
-- YOU MUST BE REGISTERED BY 8:45 --
8:45AM .................................................. BREAKFAST
9:00-10:30AM .......................................... JUDGING
10:30AM-12:30PM ................................. OPEN TO PUBLIC
12:30PM .................................................. AWARDS ASSEMBLY
1:00PM .................................................. CLEAN UP

- 9 teams / 1 me = Judging time? = Will try to be done by 10:30
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<table>
<thead>
<tr>
<th>Section/School</th>
<th>Team Name</th>
<th>Floorplan Code</th>
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<tbody>
<tr>
<td>ASEN 1400-001</td>
<td>Team Murphy's Law</td>
<td>10L</td>
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<tr>
<td>ASEN 1400-001</td>
<td>It's Always Sunny in Boulder</td>
<td>11M</td>
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<td>ASEN 1400-001</td>
<td>1 w/ da 4th</td>
<td>12S</td>
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<td>ASEN 1400-001</td>
<td>Apollo 18 (Team 1)</td>
<td>13M</td>
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<tr>
<td>ASEN 1400-001</td>
<td>Space Cowboys</td>
<td>14M</td>
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<td>ASEN 1400-001</td>
<td>Strategic Failure</td>
<td>15M</td>
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<td>ASEN 1400-001</td>
<td>Team 5</td>
<td>16M</td>
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<td>ASEN 1400-001</td>
<td>Time Stoppers</td>
<td>17M</td>
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<tr>
<td>ASEN 1400-001</td>
<td>Over Built and UnderPaid</td>
<td>18M</td>
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Announcements:
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Thursday...

Guest Speaker – The Future of Space

Colorado Space Grant Consortium
Next Tuesday (Class)

Team Videos and Space Grant Projects
Next Tuesday (Night)

Final Presentations

Start promptly at 6 PM

DLC 1B70  - Pizza but BYOB
Next Thursday

Last Class!

Course Review, Possible call from ISS
Questions?
Spacecraft Power or Orion and Career Advice

Paul Anderson
Lockheed Martin
Spacecraft
Electrical Power Subsystem (EPS)
Overview

Paul M. Anderson
Lockheed Martin Astronautics
(303) 971-4519
EPS Subsystem - What is it and What does it do?
EPS Subsystem - What is it and What does it do?

- **(4) Major Functions of the Electrical Power Subsystem**
  - **Produces / Collects Electrical Power**
    - **Nuclear**
      - Plutonium-Based Radioisotope Thermoelectric Generators (RTGs) – Planetary Spacecraft
      - Uranium-Based Fission Reactors – Very Few (SNAP; TOPAZ)
    - **Solar**
      - Silicon Solar Cells (Standard & High Efficiency) – Commercial & Low Cost Applications
      - Gallium Arsenide Solar Cells (1, 2, 3 Junction) – Commercial, LEO, GEO, Planetary Applications
      - Rigid, Flexible, Concentrating Arrays
  - **Stores Electrical Power**
    - **Batteries**
      - NiCd (Low-Cost; Short Mission Life Applications)
      - NiH₂ (Workhorse Technology for LEO, GEO, Planetary Applications)
      - AgZn (Limited Life Cycle Applications – Mars Pathfinder)
      - Lithium Ion (Upcoming Technology – Mars Exploration Rover; DOD Experimental Applications)
  - **Controls & Conditions Electrical Power**
    - Power Regulators
    - Battery Chargers
    - Power Converters
  - **Distributes Electrical Power**
    - Power Switches (Mechanical or Electrical)
    - Fuses / Electronic Circuit Breakers
How Much Power Does a Spacecraft Need?
How Much Power Does a Spacecraft Need?

• Small (Light-Bulb Sized)
  – Mars Climate Orbiter; Mars Odyssey: 300W
  – Mars Polar Lander; Mars Exploration Rover: 150W
  – Stardust; Genesis: 200W

• Medium (Hair Dryer Sized)
  – Mars Reconnaissance Orbiter (1kW)
  – Commercial & Military Communication Satellites (1kW - 15kW)
  – Weather Satellites (2kW - 5kW)
  – Classified Satellites (Can’t Say)

• Large (House-Sized)
  – Hubble Space Telescope (25kW)
  – NASA / International Space Station (50kW)
  – Project Prometheus / Jupiter Icy Moon Orbiter (JIMO) – In Work

• Monster (City-Sized)
  – Lunar & Martin Outposts (100kW - 1MW)
  – SDI Weapons Platforms (100MW+)
What Gets Powered on a Spacecraft?
What Gets Powered on a Spacecraft?

- Computer
- Power (Battery, Electronics)
- Attitude Control Equipment (Star Cameras, IMUs, Reaction Wheels)
- Telecommunication Equipment (RF Amplifiers)
- Thermal Control (Heaters)
- Propulsion Thruster Valves
- Payload (What the Spacecraft Actually Does)
What Does a Solar Powered EPS Look Like & How Does it Work?

Solar Array
- **Lander Cruise**
  - 30 Strings
  - 7.5 mil GaAs/Ge 1J
- **Lander Landed**
  - 31 Strings
  - 7.5 mil GaAs/Ge 1J
- **Orbiter**
  - 72 Strings
  - 7.5 mil GaAs/Ge 1J

Battery Assembly
- Single NiH2 Battery
- (11) 16 A-Hr CPVs
- "Extra" IPV Cell (L)
- Telemetry

Charge Control Unit (CCU)
- CCU Card “A”
- CCU Card “B”

Power Distribution & Drive Unit (PDDU)
- DC-DC HKPS Card
- EPS Switch Card
- Switch Logic Card
- Load Switch Card (2)
- 28V DC-DC Converter Card
- Slave I/O Card
- Motor Driver Card
- EPS Module I/F Card
- EPS Backplane

Pyro Initiator Unit (PIU)
- Pyro Initiator Card (1-O; 2-L)
- Prop Valve Driver Card (1-O; 1-L)

Command & Data Handling (C&DH)

Unregulated Loads
- Propulsion
- Telecom
- AD&C
- Thermal
- Cameras
- MVACS (L)

Regulated Loads
- DST/CDU/TMU
- PMIRR (O)

Motor Loads
- S/A’s (O & L)
- HGA (O), MGA (L)

NSIs
- G&H Actuators
- Thrusters
What Does an Nuclear Powered EPS Look Like & How Does it Work?

(2) Advanced Radioisotope Power System (ARPS) - GFE

- BOL
- EOL

Current

Voltage

- (4) General Purpose Heat Sources (GPHS)
- (16) AMTEC Cells
- 4.7V per Cell
- 19 kg
- 15.3” (Diameter)
- 105We @ EOL

16 A-Hr Battery Assy

8 CPVs

Power Control & Distribution Module (PCDM) - LMA

- Shunt Control Module
- Battery Control Module
- Boost Regulator Module
  - Switch Logic Card
  - EPS Switch Card
  - Load Switch Card #1
  - Load Switch Card #2
  - Dual Slave I/O Card
  - High Efficiency HKPS Card
- EPS Module I/F Card
- EPS Backplane

Power

PVDM Power

SSPA Power

Safety Relay Assy

Pyro Initiator Unit (PIU) (LMA)

- Pyro Initiator Card (1)
- Prop Valve Driver Card (1)

Pyro Initiator Unit (PIU) (LMA)

- Telemetry

Power

Latch Valve Thrusters

S/C NSIs

Star48 NSIs

Shunt Resistor Banks (16 Legs)

Command & Data Handling (C&DH)

Loads

- Prop & Batt Xdcrs
- SDST
- IMU, Star Tracker
- Payloads
- Thermal
- Star 48

Shuttle/IUS/T0 I/Fs

28V Power/RSense

Trickle Charge

Hardline Tlm

Safety Inhibits

Power
What Sort of Tasks does an EPS S/C Engineer Perform?

- **Technical**
  - Calculate How Much Power is Required to Operate the Spacecraft
  - Calculate How Big a Solar Array or Nuclear Source is Required
    - Predict Power Variations on a Day to Day / Hour to Hour Basis
  - Calculate How Big a Battery is Needed for Eclipse Periods
    - Depth of Discharge / Life Cycles
  - Design & Test the Circuitry to Control, Condition and Distribute Power
    - Both Digital and Analog Circuit Design and Analysis
  - Derive the Software Requirements Necessary to Manage the EPS
  - Support Spacecraft Level Integration & Testing
  - Troubleshoot Problems as they Occur
  - Support Launch Operations @ KSC or VAFB
  - Operate the Spacecraft During the Mission
What Sort of Tasks does an EPS S/C Engineer Perform?

- **Programmatic**
  - Manage Large Budgets and Complex Schedules
  - Manage Subcontractor Suppliers
  - Present Status to Management and the Customer
    - Both Technical and Programmatic
  - Supervise the Supporting Engineering Staff
  - Give the Final GO for Launch
  - Write Technical Papers, Give Presentations to Industry & the Public
What Sort of College Majors do EPS Engineers Have?

- Electrical Engineering
- Mechanical Engineering
- Physics
- Chemical Engineering
- Nuclear Engineering
- Aerospace Engineering
- Computer Science
- Engineering (General)
- Engineering Management
Spacecraft

Electrical Power Subsystem (EPS)

Overview

Paul M. Anderson
Lockheed Martin Astronautics
(303) 971-4519
Practical Advice from a “Real” Engineer

Paul M. Anderson
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What are the Best Things About Your Job?

• Very Technically Challenging and Interesting Programs
  – Yes, this is Rocket Science

• Working with Incredibly Talented (and Under-Appreciated) Individuals

• Traveling (Some)

• Interfacing with the Public

• Launches!
What are the Worst Things About Your Job?

• **Failures**
  – Good Way to End Up on Leno & Letterman

• **Long Hours**
  – 50-60 Hours / Week During a Program is Typical

• **High Stress**
  – Lots of Technical Problems (without them we have no jobs)
  – Lots of Cost/Schedule Problems
  – High Visibility Programs (Company and General Public)

• **Lots of Traveling**
  – Most Business Trips are a Drag

• **Personnel Problems**
  – Very Few, but They’re Your Worst Nightmare
What do I Need to do to become a Successful Engineer?

• **Apply and Get Accepted to a *Respected* Engineering School**
  – Transfers from 2 Year Community Colleges are Now Widely Accepted and an Excellent, Cost-Effective Route
  – Does Not Have to be the #1 School in the World
    • But Should be Respected
  – Masters Degrees are Preferred, but can be Obtained Post-Employment
    • Good Tool to Help Avoid the Engineering and/or Management Glass Ceiling

• **Good Grades (within Reason)**
  – Extra-Curricular Activities are Also Strong Hiring Discriminators

• **Get Some Real-World Work Experience Before Graduating**
  – Taco Bell Doesn’t Count

• **Interview Well!**
  – If you can’t Write or Speak, Learn to do So
What do I Need to do to become a Successful Engineer?

• Get Along Well with People / Be a Good Team Player

• Be Diverse & Willing to do Multiple Things – Continually Broaden!

• Have a Positive Attitude

• Be Willing to Make Hard Decisions

• Be Thick Skinned but not Calloused