Practical Advice from a “Real” Engineer

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

Power
- PIU Power
- Thermal Battery (L)
- MFB Secondary Pwr

Telemetry
- Optical Encoders
- PIU Power

MFB
- Power
- Optical Encoders
- PIU Power
- MFB

Power Distribution
- Pwr Tim
- CCU Card
- Power
- Discrete Commands & Telemetry
- Power
- Discrete Commands & Telemetry
- Power
- Command & Data Handling (C&DH)
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What Does an Nuclear Powered EPS Look Like & How Does it Work?

- **Power**
  - (2) Advanced Radioisotope Power System (ARPS) - GFE
  - (4) General Purpose Heat Sources (GPHS)
  - (16) AMTEC Cells
  - 4.7V per Cell
  - 19 kg
  - 15.3” (Diameter)
  - 105We @ EOL

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

- **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

- **Latch Valve Thrusters**
  - S/C NSIs
  - Star48 NSIs
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
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