

## Designing Mass Spectrometer Systems for Harsh Environments



## Overview

- The Project
- Electrical Concepts
- Fluid / Sample Concepts
- Mechanical Concepts
- Human Factors Concepts
- Specific Components of Interest

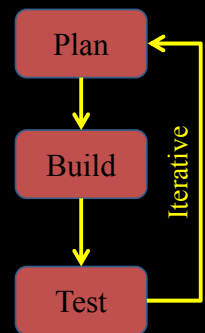
## Project Lifecycle

- Applicable to all projects
- Define Design Freezes / Review Cycles
  - Proof-of-Concept, Prototype, Beta, Final
  - 30/60/90
- Define Metrics for Completion of Review Cycle
  - Make metrics reasonable
  - Allow for contingency (more for early cycle, less for later)
- Documentation
  - Hand drawn sketch, 2D CAD, 3D Model
  - Component Spec Sheets, Accumulated Specification Matrix

*"He who fails to plan is planning to fail"* Winston Churchill

## Design / Development Cycle

- Identify Customer / Application
  - What is the end product
  - If multiple applications, conflict?
- What are the System Requirements
  - Performance
  - Environment (Natural, Induced)
- Develop Testing
  - Requirements
  - Application
  - Customer (Communicate / Evaluation)



### Electrical – Test Points

- Power
  - Primary Power (External Indicator)
  - Sub-bus Power
- Signals
  - PCB Loops
  - Test Boxes
  - Test Cables



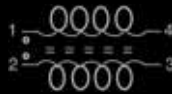
Similar Design  
Concept for  
Fluid System

### Electrical – Control & Data Acq.

- Isolate Signal Return from Chassis/Earth Ground
- Control – Analog
  - Overvoltage Protection
  - Ability to Drive or Sink Load
- Output or Input – Digital
  - Verify Compatible (TTL, CMOS, etc.)
  - Ability to Drive or Sink Load (Volt Level and Current)
- Input – Analog
  - Single / Differential Inputs (True/Analog vs. Digital)
  - Overvoltage Protection
  - Bandwidth Limiting – Filtering
    - Digital vs. Analog
    - Passive Low Pass, Active, Higher Order

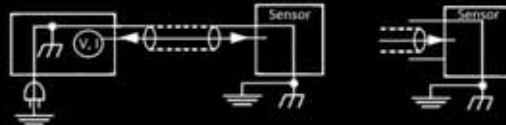
### Electrical – Power Distribution

- Derating Components (NFPA 70 – NEC)
  - Wire Bundles
  - Thermal
  - Connector and TB ratings
- Redundancy for Reliability
  - Pin / Socket has poor MTBF
- EMI / Noise (MIL-STD-461)
  - Filter Circuits (Common Mode, Differential Mode)
  - Surge Suppression (Transorbs)



### Electrical – Signal Distribution

- EMI / Noise (MIL-STD-461)
  - Filter Circuits (Common Mode, Differential Mode)
  - Surge Suppression (Transorbs)
  - Chassis Isolation
  - Signal and Power Return Isolation (Return  $\neq$  Chassis)
  - Twisted Pairs
  - Shielding (Cable, Harnesses, PCB Traces)
  - Avoid Ground Loops (Connect 1 side, isolate other)



### Electrical – Signal Redundancy

- Connector Pin/Socket have high failure rate
- Level of Effort
  - Connectors only (Multi-pin)
  - Same sensor, 2 path (2 Data Acquisition)
  - 2 sensor
- Concern about Conflicting Data
  - Voting
  - Primary / Secondary
  - Design in; don't use

### Mechanical – The Cantilever

- Stabilize all components
  - Vibration
  - Acoustics
  - Shock
- Access
  - Replacement
  - Maintenance
  - Validation
  - Calibration



### Mechanical – The Cantilever

- Printed Circuit Boards
  - Capacitors
  - Inductors
  - DC/DC Converters
  - Relays
- RTV
  - Electrical Insulating
  - Thermal Conducting



### Mechanical – Vibration/Acoustics

- Vibration Dampeners
    - Rubber Stand-offs (Compression)
    - Diaphragm Stand-offs (Compression)
    - Spring (Compression)
    - Wire Rope (Compression / Extension)
  - 1 Band per Material
    - Multi-stage Spring
    - Spring / Diaphragm
  - Wire Rope
    - Excellent Motion
    - Easily Tuned
    - Bulky
- ✓ Component Damage  
 ✓ Component Adjustment  
 Potentiometers



## Mechanical – Fasteners

- Prevent Galling
  - Fluid Fittings Lubrication
  - Krytox, Braycote, etc. (MIL-PRF-27617)
  - Consider treatments (Electropolish, Silver, etc.)
- Threaded fasteners
  - Ensure Quality Material, match with application
  - SAE, ASTM, other specifications
- Securing of fasteners
  - Lock Washers (spring, tooth, etc.)
  - Lock Nuts (Nylon, etc.)
  - Threadlocking Adhesive (ASTM D5363)
  - Safety Wire / Cotter Pins (NASM33540)

## Mechanical – Part Marking

- Marking Items
  - Limited Life Items
  - Routine Maintenance (Calibration)
  - Any Level of Traceability
- Determine Relevant Information
  - Part Number
  - Serial Number
  - Cage Code
  - Date of Mfg.



## Mechanical – Assembly / Fabrication

- Allow for Fabrication Errors
  - Slotted holes are your friend
  - Fluid components are often not accurate/reproducible
- Understand when precision is needed
  - Can be an unnecessary cost
  - Can cause damage to mounted components
- Ensure that Assembly is Feasible
  - Does the right Tool have Access?
  - Small Hands / Big Hands

## Mechanical – Torque Issues

- Know the Torque Range
  - ConFlat, VCR, Swagelok, JIC (Metal)
  - NPT, KC (Teflon, Nylon, slip-polymer)
  - Boss, BPT, other straight thread (elastomer)
- Ensure Torque can be Accomplished
  - Access
  - Backing Nuts
  - Prevent Over-torque secondary



## Fluids – Cleanliness

- Have Plan/Procedure to Fabricate & Maintain Clean
- Define Cleanliness Level at Project Outset
  - Particulate Count (ASTM F 312)
  - Non-volatile residue (NVR) (ASTM F 331)
- Wide Variety of Methods and Specifications
  - ASTM A 380 – cleaning, descaling, and passivation
  - ISO Standard 14644 – Clean Room Class Limits
  - (there are many others, MIL, SAE, etc)
- Cost is variable (examples with full test & doc)
  - ~\$50 for small vacuum chamber, ~\$75 hand valve
  - ~\$250 for electromechanical valve (rebuild)

## Fluids – Sample Integrity

- Minimize Dead Volume
  - Prioritize Sensor Locations
  - Optimize with fluid conductance
  - Understand Valve Flow
- Mixing
  - Restrict / Promote where needed
- Leak Integrity
  - Know Sample (Gas, Liquid) and Environment
  - Understand Gradients (Pressure, Concentration, etc.)
  - What Materials (SST, AI, Elastomer, Membrane, etc.)
  - Fittings (NPT, Swagelok/A-lok, VCR, Con-Flat, Boss, etc.)

## Human Factors – Access / Maintenance

- Limit Directions of Access
  - All from Above or Back, etc.
- Limit Strain for Access
  - “Line of Sight”
  - Ability to use hands, or tools
- Ensure Maintenance doesn't Compromise Integrity
  - Fluid Fittings, Electrical Cables



## Human Factors – HMI

- HMI should have familiar features
  - Consistent with common S/W products
  - Consistent with Technology / Field of Study
- Use Consistent Jargon
  - Avoid alternate names when function is well established
- Implement Security
  - Operator Mode, Administrator Mode, etc
- Hardware Security
  - Prevent Incidental Actions (Switch Covers, Cable Removal)



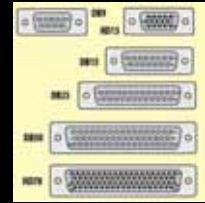
No customer is willing to completely retrain a workforce. Keep it simple!

## Components – Mass Analyzer

- Stability
  - Mechanical, Thermal, Electrical
- Interface with Vacuum Chamber
  - Electrical Feedthrus
  - Mechanical Support
- Issues of Concern
  - Vibration Susceptibility
  - EMI Susceptibility
  - Thermal Susceptibility

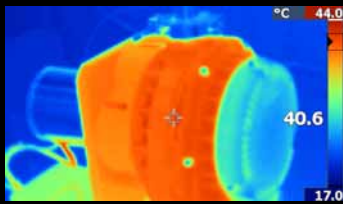
## Components – Electrical Connectors

- Mechanically Stabilize
  - Minimize Stress on pin/socket
  - Capture Connectors
  - Use Backshell
- Prevent Inadvertent Cross-connect
  - Polarized, Keyed
  - Alternate Key Position for Similar
  - Label Plugs and Junctions
- Environmental Concern (NFPA Class 1 / Div 1 or 2)
  - Potted (Stycast), Molding
  - Alternate Key Position for Similar
  - Label Plugs and Junctions



## Components – Rough Pumps

- Technology
  - Dry vs. Oil
- Power Source
  - AC (more common)
  - DC (more portable)
- Issues of Concern
  - System Contamination (oil, particulate, etc)
  - Induced Vibration
  - Induced EMI
  - Thermal
  - Size, Weight



## Components – HV Pumps

- Technology
  - Turbo, Drag, Ion, etc.
- Power Source
  - AC or DC
  - Can have High Voltage
- Issues of Concern
  - Vibration Susceptibility
  - Induced EMI (Inductive Load)
  - Contamination Susceptibility
- **Don't forget about Location to Mass Analyzer!**

## Acknowledgements

- Eric Gore
- Guy Naylor
- David Floyd
- Charles Curley
- Tim Griffin
- Bradley Burns
- Carlos Mata
- Gary Klintworth
- Damion Lucas

