RAPID PROTOTYPING

"Practice Makes Perfect"

Ed Mauldin

NASA Project Manager Retired

Goal

- Improve
  - Schedule
  - Cost
  - Technical Performance
  - Reliability
- Effectiveness has been demonstrated on SAM/SAGE Series

Case History

- SAM II; launched on Nimbus 7/Delta, 1978
  - Operated 15 years before ops terminated
- SAGE; launched on AEM 2/Scout, 1979
  - Operated 3+ years before S/C battery failure
- SAGE II; launched on ERBS/Challenger, 1984
  - Still Operating
- SAGE III; launched on Meteor/Zenit, 2001
  - Still Operating

Performance Against Objectives

- These experiments have achieved initial scientific objectives and much more
- Measurements were key in understanding the chemistry of stratospheric ozone depletion
  - 1995 Nobel Prize in Chemistry awarded to Paul Crutzen, who used SAM/SAGE data in his research that explained the role of Polar Stratospheric Clouds (PSCs) in ozone destruction
  - SAM II data discovered PSCs and SAM/SAGE series provide the primary PSC data base
- Experiments were developed within schedule and budget

Rapid Prototyping

Why?

- Early discovery, troubleshooting and fix of Design, Analysis, Manufacturing and Testing Problems
  - Proto hardware available earlier than flight hardware
- Less formality in Quality Control and Configuration Control program allows:
  - Streamlined manufacturing and testing
    - Machinists and test technicians are more involved in the design process
  - Troubleshooting problems to be streamlined
    - Can redline, repair and retest on the fly
- Must keep immaculate informal records and log of all changes or else you will lose Configuration Control

Rapid Prototyping

How?

- Design Analysis ⇨ Hardware ASAP
  - Instead of looking for the perfect design on paper, get an early design built and tested
  - Build, test, data analysis, redesign, retest, new data analysis, redesign, retest, etc.
    - *Make it Work !*
- Testing must include:
  - Performance testing
  - Interface testing
  - Environmental testing
  - Simulated orbital operations

Rapid Prototyping

- First Generation (SAM II) developed under Nimbus PO rules
  - 3 models developed (EM, PFM and FM)
- EM prototyped new designs for
  - Optical
  - Pointing System
  - Structural/Mechanical
  - Electrical

Rapid Prototyping

SAM II, the first generation

- *Nothing worked on first EM build!*
  - Numerous Optical problems
  - Numerous Structural/Mechanical problems
  - Numerous Manufacturing problems
  - A few Electrical/Control System problems
- However, after several test, redesign, retest cycles, we made the beast work!

Rapid Prototyping

SAGE, the second generation

- Heritage designs from SAM II used where ever possible
  - *Why go back to the headaches of the first generation?*
- Prototyping again done on all new subsystems
  - Grating spectrometer and interface structure
  - No need for an EM, since new proto hardware added to SAM II EM

Rapid Prototyping

SAGE II, the third generation

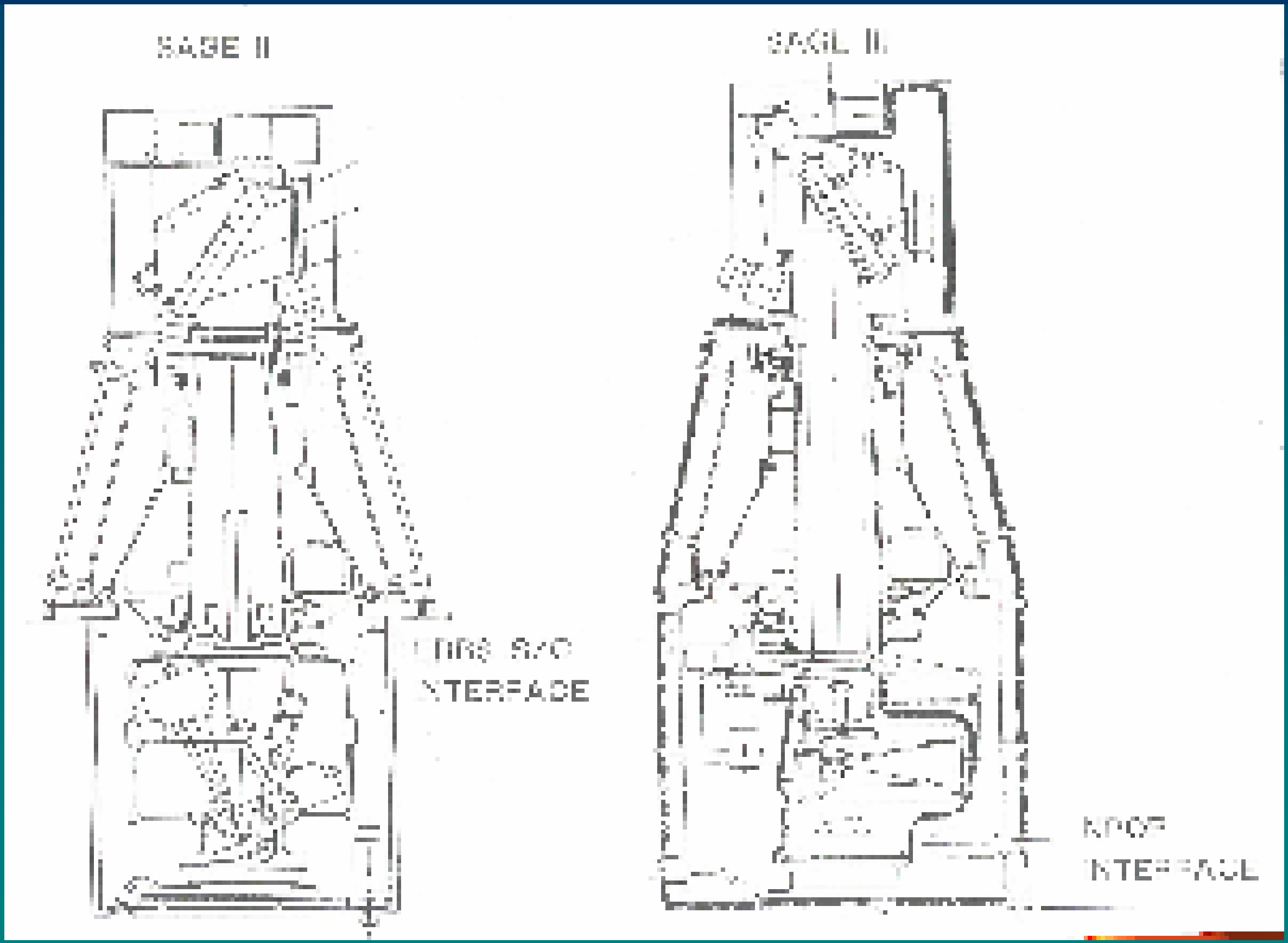
- Again, new designs for Spectrometer and Interface Structure added to the previous EM
  - We began to call this model the "Mutant SAGE"
- However, we discovered one of pitfalls
  - *A mechanical design that had worked perfectly on first 2 generations broke late in test program, requiring a last minute scramble*

Rapid Prototyping

SAGE III, the fourth generation

- Radical departure from previous optical and detector designs to make use of new detector and computer technology, and new electrical and mechanical interface design
- New telescope/spectrometer designs were forced to fit within the old Mutant SAGE gimbal structure to maximize use of SAMII/SAGE/SAGE II heritage
- Factor of 10 more expensive than SAGE II

SAGE II and SAGE III Comparison



Some Lesson Learned

- Rapid Prototyping is just an example of the old adage
  - *Practice Makes Perfect*
- If one can’t play tennis or golf on the first try, what makes them think that they can design a flight instrument on the first try - this IS rocket science!

Some Lesson Learned

- Use of rapid prototyping and heritage hardware on SAM/SAGE provided:
  - 2 and 3 year build cycles (< SAGE III)
  - Low cost instruments (< SAGE III)
  - Designs that met performance requirements and were well understood
  - High reliability and long lifetimes
    - *No instrument has failed on orbit*

Some Lesson Learned, cont.

- Sometimes you can’t reproduce a good heritage design, because:
  - Parts no longer exist
  - People no longer exist
  - Processes no longer exist
  - Blind luck ceases to exist
    - *Using a Heritage Design is not a guarantee that it is reliable - Murphy’s Law applies - use common sense!*

Some Lesson Learned, cont.

- Onboard computers and associated software are major cost drivers!
- Developing new technology is very expensive
  – *Is the additional science worth the additional cost?*