

REPORT DOCUMENTATION PAGE

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MEMORANDUM FOR PRR (In-House Presentation)

FROM: PROI (TI) (STINFO)

19 May 1999

SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-TP-FY99-0101
Dr Greg Ruderman, "SBAS: The Structural/Ballistic Analysis Section"

On-Site presentation

(Statement A)



SBAS: The Structural/Ballistic Analysis System

**Prepared for University of Illinois Center for
Simulation of Advanced Rockets**

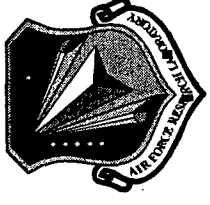
24-25 May, 1999

**Air Force Research Laboratory, Edwards Air Force
Base, California**

**Presented by:
Dr. Gregory Ruderman
AFRL/PRRM
Edwards AFB, CA**



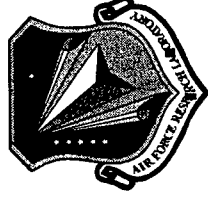
SBAS Introduction



- **In 1988, a contractual effort, performed by Thiokol, Utah Operations, began on the Air Force Structural/Ballistic Risk Assessment Methodology (SBRAM) program**
- **The intent of SBRAM was to develop an analysis methodology to predict coupled structural/ballistic response of solid rocket motors with defects and evaluate the risk of failure of these motors**
- **The result was a set of coupled analysis codes, completed in 1995, known collectively as SBAS**



SBAS Methodology

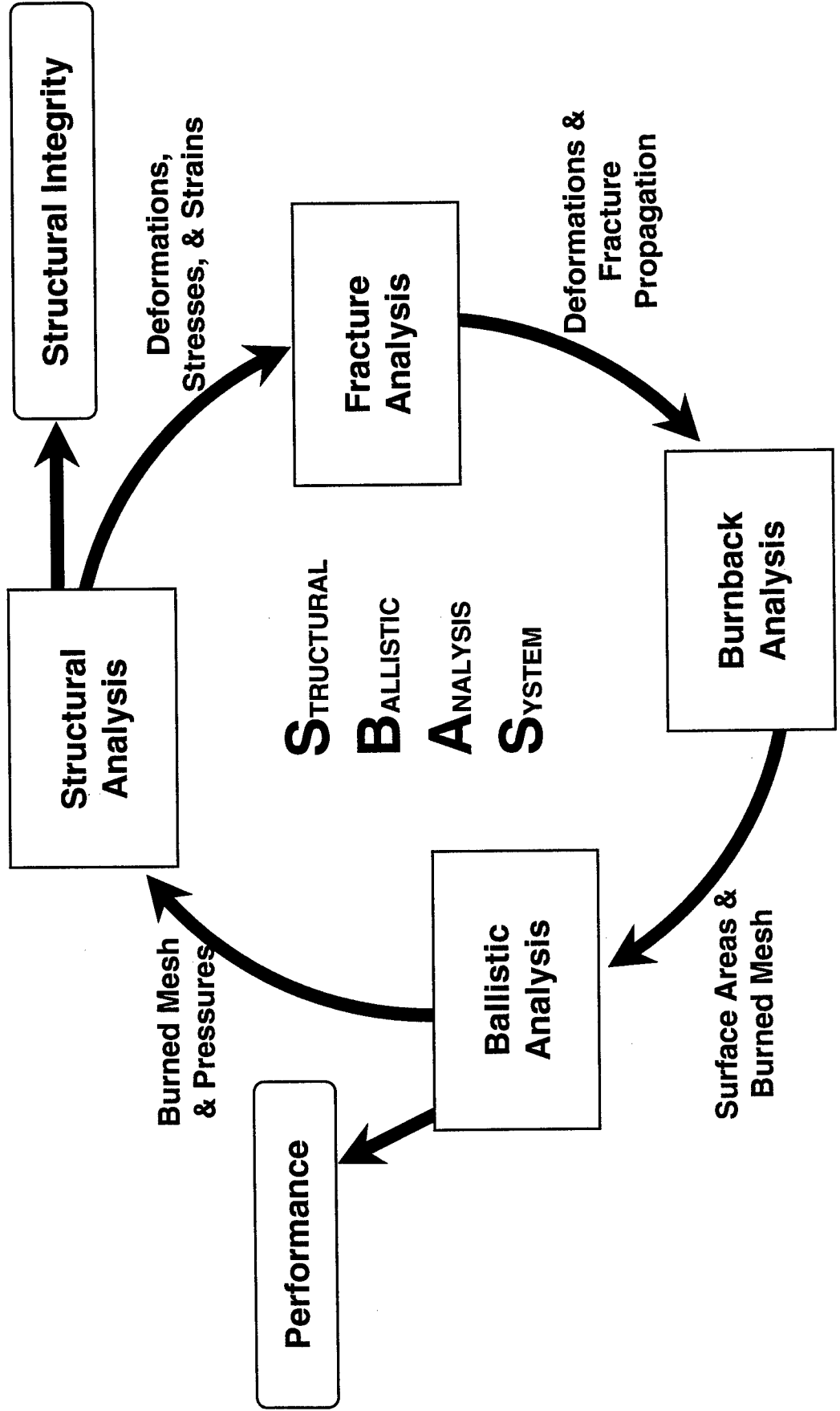
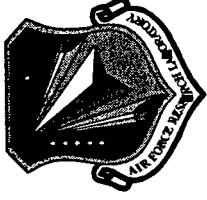


- SBAS consists of four analysis elements
 - Internal ballistics
 - crack/debond combustion
 - structural response
 - fracture mechanics
- All four elements are coupled, so an iterative solution is required

UPPER CASE

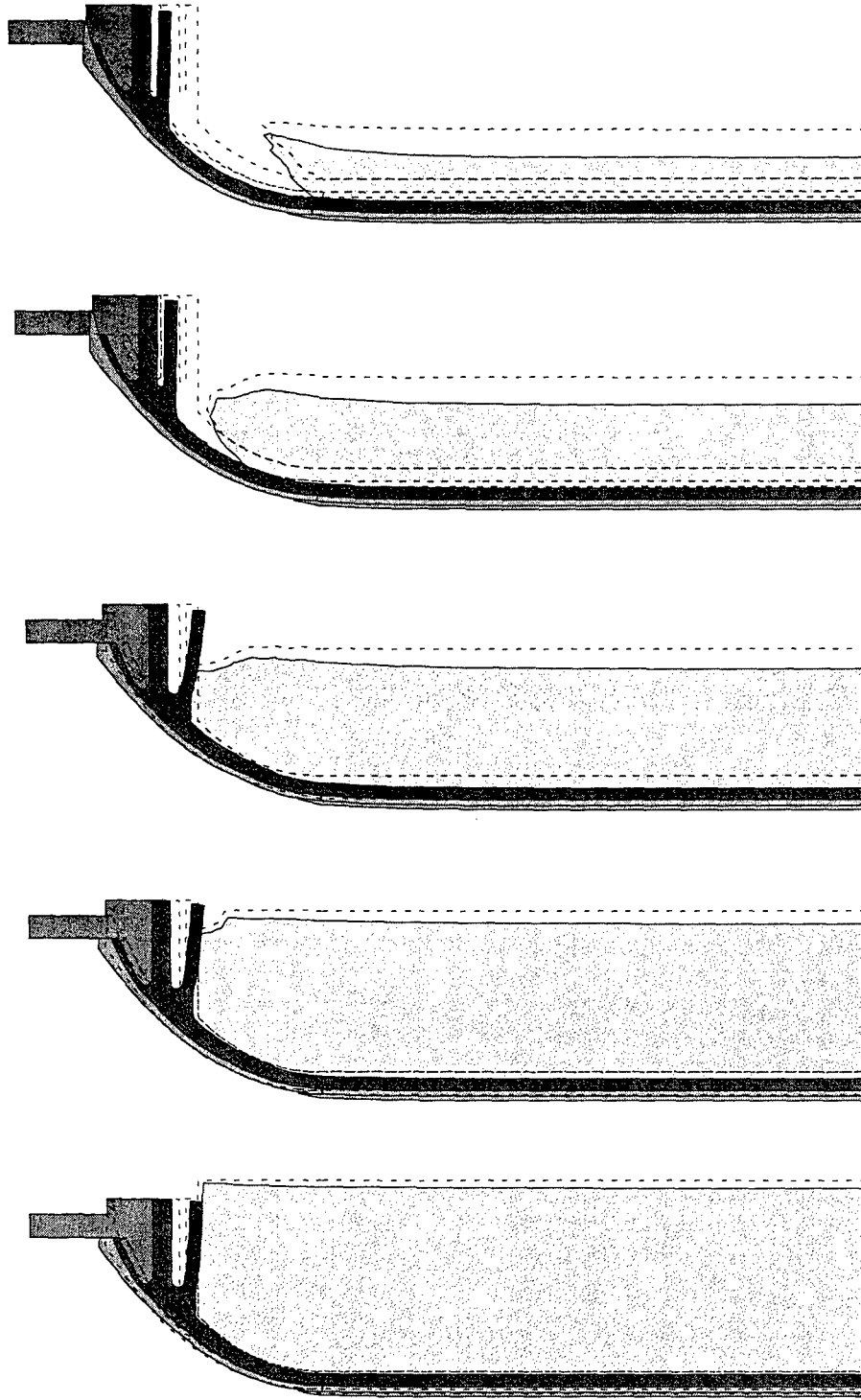


SBAS Methodology





SBAS Analysis



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SBAS Elements Executive Program



- The Finite Element INTERface (FEINT™) program serves as the SBAS executive program
- FEINT is ~~was~~ developed to provide interfaces between FEM programs and structural analysis program, but now includes interfaces to crack/debond combustion, burnback, heat transfer, ballistics, material property, and thermochemistry codes
- FEINT also includes mesh generation and post-processing capabilities



FEINT WAS
ALREADY DEVELOPED
WITHOUT IT AND
JUST ADAPTED TO
THIS USE?
OR MODIFIED?



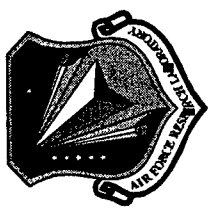
SBAS Analysis Elements-- Internal Ballistics



- **Internal ballistic solution is driven by burning surface area, which is a function of deformation and crack/debond size**
- **Variation in the burning surface area due to deformation is primarily a function of case flexibility**
- **RECESS internal ballistics code can solve
 - Grain burnback
 - Internal ballistics
 - Coupled burnback-ballistics calculations**
- **RECESS accepts and modifies FE mesh**



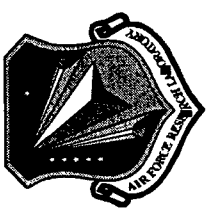
SBAS Analysis Elements-- Crack/Debond Combustion



- Crack/debond combustion solution is dependent on the shape of the crack/debond and the bore pressure
- Crack/debond combustion may be calculated using
 - 1-D quasi-steady solution for pressures in the crack (CCM code)
 - Transient solution to ballistics in the crack (CDCA code)



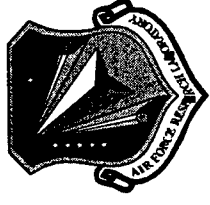
SBAS Analysis Elements-- Motor Structural Response



- **The structural response of the motor is dependent on material properties and the load history provided by the internal ballistic solution and crack combustion solutions.**
- **Grain burnback and crack growth are also accounted for so the model reflects the current point in time.**
- **Structural response may be calculated by various commercial/in-house codes (ABAQUS, ANSYS, TEXLESP, etc.).**



SBAS Analysis Elements-- Fracture Mechanics

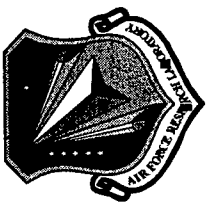


- The fracture mechanics analysis is essentially a postprocessing calculation performed using the structural solution. 4-
- Fracture mechanics is implemented in FEINT and can compute linear and non-linear J-integrals and allows for thermal loading. 28-



SBAS Solution Methodology

Initial Response Estimate

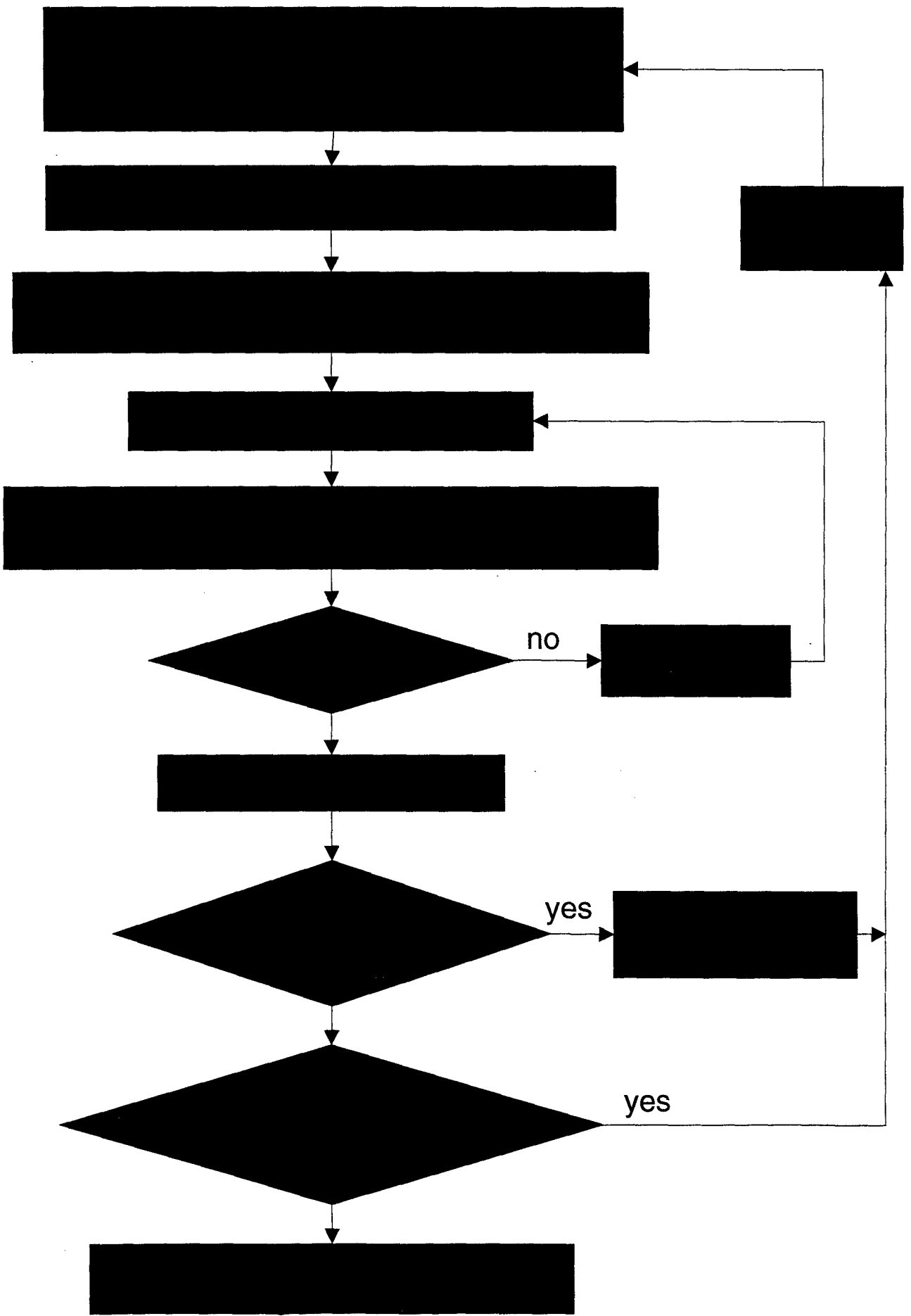


- **Step 1: Initial response estimate**
 - **Input FE model with material properties, lit nodes, restraints**
 - **Compute initial undeformed ballistic solution**
 - **Apply pressure at the end of the ignition transient**
 - **Perform initial structural analysis**
 - **Perform initial fracture analysis**



SBAS Solution Methodology Incremental Coupled Solution







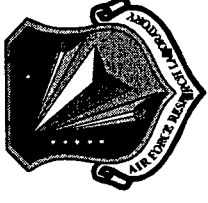
SBAS Shortcomings



- **Not a turnkey solution**
- **FEINT does not build an input deck with history**
- **Requires “informed user interaction” to arrive at a solution**



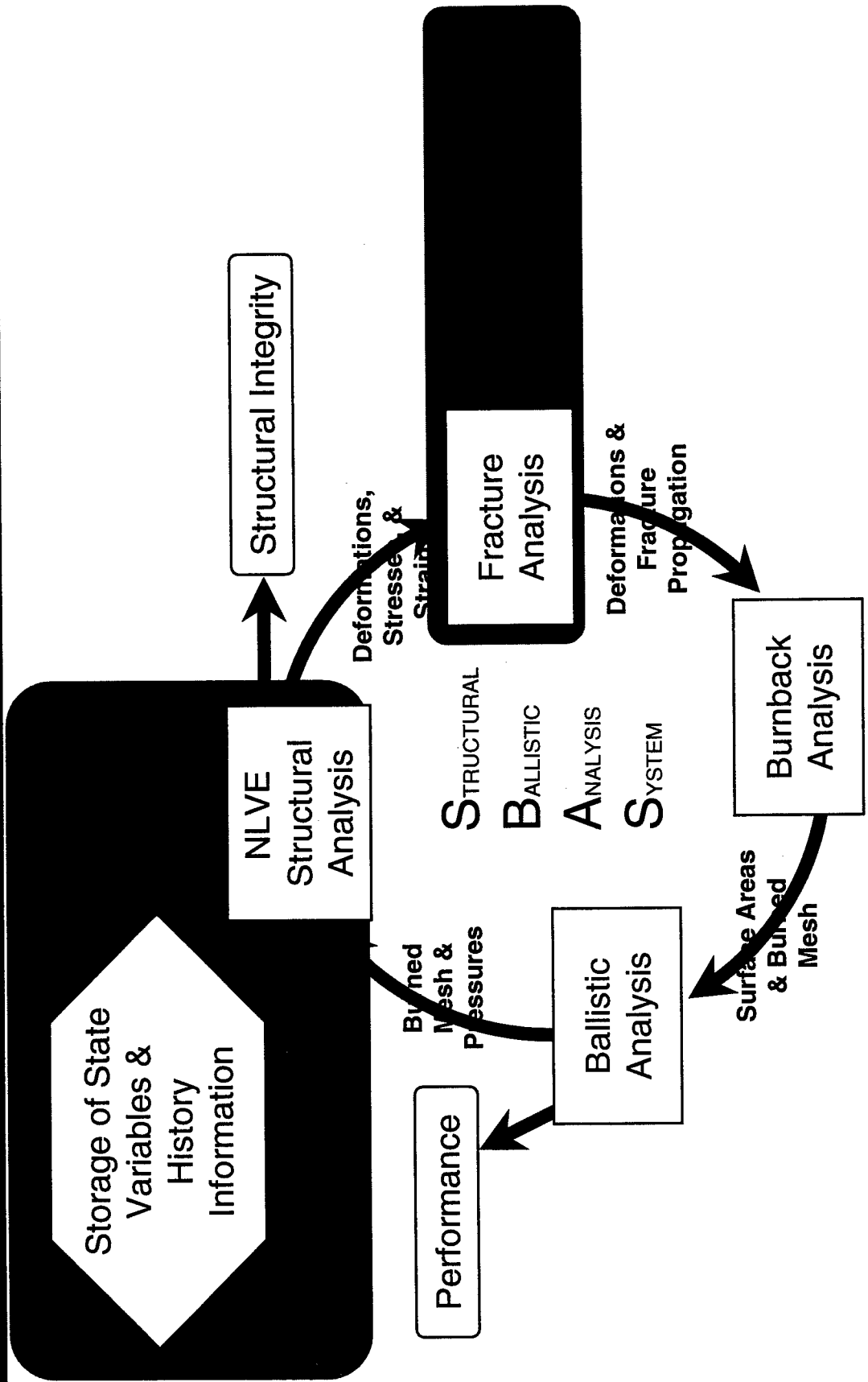
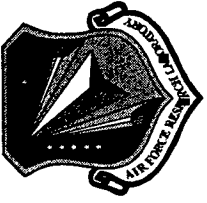
Aging and Surveillance SBAS Upgrades



- **Under the Air Force Aging and Surveillance programs SBAS will be upgraded to SBAS II**
- **Under the Service Life Prediction Technology program**
 - **Microstructurally-based nonlinear viscoelastic model will be implemented.**
 - **Capability to use history-dependent models**
- **Under the Critical Defect Assessment program**
 - **Flow analysis codes will be coupled with structural analysis to automate structural/ballistic interaction analyses**
 - **Fracture analysis capabilities will be upgraded**
 - **Automated meshing from NDE data**



SBAS II





Conclusions



- **SBAS is a coupled suite of codes for SRM analysis capable of simulating structural/ballistic interaction in “normal” and flawed motors**
- **Upgrades to SBAS under the AF Aging and Surveillance programs will enhance both the system’s capability and usability, bringing it closer to a fully-automated analysis system**