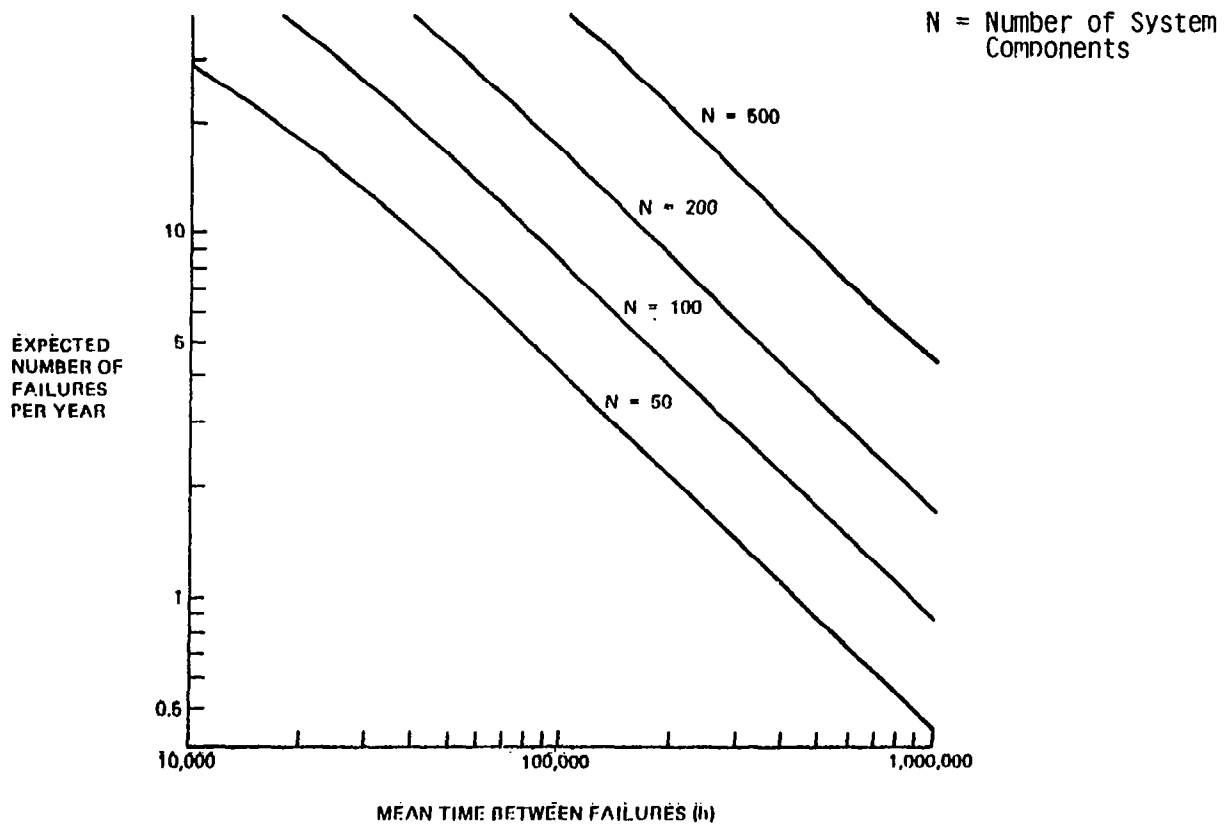A PROGRAM PLAN FOR THE DEVELOPMENT OF

FAULT TOLERANT LARGE SPACE SYSTEMS

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## Objectives

- Establish the need for fault tolerance in LSS

- Discuss the unique characteristics of LSS which affect fault tolerance

- Summarize the status of fault tolerant systems for LSS

- Discuss a program plan to validate and demonstrate the concept of fault tolerance for LSS

## Establishment of the Need for Fault Tolerant LSS

N = Number of System Components

N = 500

N = 200

N = 100

N = 50

EXPECTED NUMBER OF FAILURES PER YEAR

10

5

1

0.5

10,000        100,000        1,000,000

MEAN TIME BETWEEN FAILURES (h)

# Characteristics of LSS That Affect Fault Tolerance

- Dimensionality

    - Will have to consider a much larger number of components than in any previous application

    - May affect the achievement of real time operation and computational accuracy

- Precise accuracy and stability requirements

    - Small failures will have to be detected and isolated quickly

- Structural mode and physical displacement effects on sensors

    - May be comparable in magnitude to the failures which must be detected

- Environmental effects

    - Dynamic effects such as large angle slewing maneuvers
    - Thermal effects may produce changes in modal characteristics

- Spillover (Model Order Reduction) effects

    - May introduce uncertainties which can be falsely interpreted as failures

- Many diverse types of sensors present

    - Must be collectively accounted for if system wide fault tolerant capability is to be achieved

- Multiple experiments operating on a single LSS

    - Interactions among experiments may result in false alarms

    - A robust fault tolerant system may be required to tolerate changes in modal characteristics with experiments

- The modal frequencies may be in the controller bandwidth

    - Filtering to reduce modal effects and improve fault tolerant capability may not be possible

## Status of Fault-Tolerant Technology for LSS

- Little work has been done in this area

- A large body of knowledge concerning fault tolerant systems has evolved in spacecraft and avionics applications

- This material forms a solid foundation for the development of fault tolerant technology for LSS


## Elements of a Program Plan to Validate the Concept of Fault Tolerance for LSS

- System modeling

    - Generate an analytic model of the LSS

- Environment modeling

    - Define LSS tasks, maneuvers and disturbances

- Requirements definition

    - Define LSS accuracy, stability and reliability requirements

- Component modeling

    - Define analytic models, error effects, noise, flexibility effects, etc.

    - Uncertainties establish the fault tolerant capability of LSS

- Fault tolerant techniques development

    - Develop algorithms to detect and isolate faults and reconfigure LSS

- Simulation development

    - Both nonreal time and real time capabilities will be needed

- Development of a fault tolerant data processing capability

    - Needed to carry out computations associated with the LSS

    - A firm basis for this technology exists

Elements of a Program Plan to Validate
the Concept of Fault Tolerance for LSS
(concluded)

- Conceptual design

    - Preliminary definition of algorithms, components,
      architectures, etc. and assessment of design
      alternatives

- System design

    - Detailed and specific determination of parameters,
      components, architectures and algorithms for selected LSS

- Preliminary implementation

    - Definition of system software and hardware

    - Partitioning of functions among subsystems

- Validation of fault tolerance concept and demonstration
  of capability

    - Use simulation of complete LSS

- Requirements evaluation

    - Use simulation to assess ability of fault tolerant
      LSS to meet accuracy and stability requirements

    - Analytic techniques must be employed to evaluate
      the reliability of the LSS

Conclusions

- There is a definite need for fault tolerance in LSS

- LSS have unique characteristics which impact fault tolerance

- Very little work has been done regarding fault tolerance for
  LSS although a solid base exists from spacecraft and avionics
  applications

- A program plan for the validation and demonstration of the
  concept of fault tolerance for LSS has been developed