MIT Subject 16.885J/ESD.35J
Aircraft Systems Engineering

F/A-18 FLIGHT CONTROL SYSTEM

HENRY HARSCHBURGER
Boeing (Retired)

Flight Control Systems
For Tactical Military Aircraft

- Flight Control System Architecture
  - No Universal FCS Designs
  - Many Different Architectures Will Work
  - Any System Will Have Pros and Cons
- Factors Influencing Architecture
  - Aircraft Mission
  - Aircraft Configuration
  - Procuring Agency
    - Service History With Similar Aircraft
    - Experience
    - Preferences

Flight Control Systems
For Tactical Military Aircraft

- Other Factors Influencing Architecture
  - Flight Control System Team (Government/Contractors/Suppliers)
    - Experience of Team Leaders
    - Lessons Learned
    - Team Members Strongly Held Preferences
    - Organization
      - Total System Vs Subsystem/Component
      - System Integration Responsibility
      - Integration of Interfacing Systems/Subsystems
      - System Testing
      - Development Plan / Integrated Schedules

Brief History of F/A-18A

- 1974 Navy Fighter Study
- DOD Direction HI/LO Mix (F-14/F-15 & Low Cost Fighter)
- USAF and Navy Use Light Weight Fighter YF-16 or YF-17
- Contractor Teams
  - General Dynamics - LTV
  - Northrop - McDonnell Douglas
- Flight Controls
  - YF-16 Fly-By-Wire
  - YF-17 Hydro-Mechanical and CAS
- USAF Selected the YF-16
- Navy Selected Naval Version of YF-17 to Become F/A-18
- F/A-18 Required Changes to YF-17 Flight Control System

Evolution of F/A-18A Flight Control System

F- 4 SFCS (FBW)

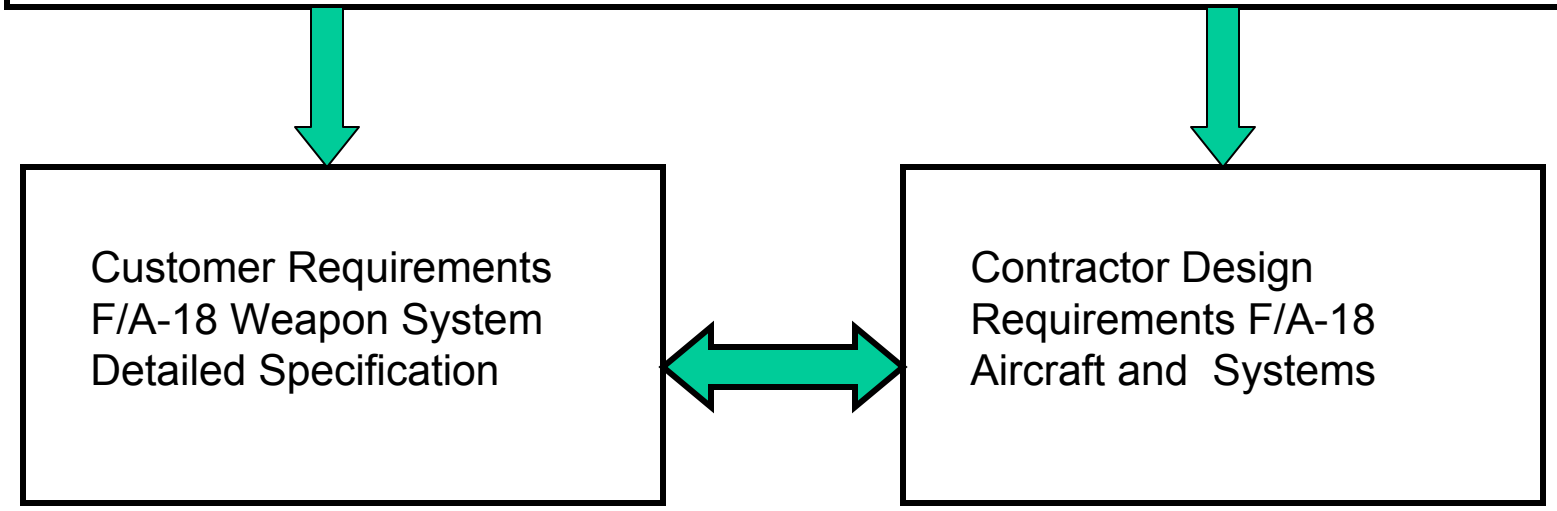
F- 4 PACT

F-15

YF-17

F/A-18 Requirements Development

- Customer Requirements
- Experience With F-4 and A-7 Aircraft
- Lessons Learned From Development Programs
- Navy Lessons Learned Database (all aircraft)
- Contractor / Supplier Experience on Recent Programs



F/A-18 Flight Control System Requirements

F/A-18 Weapon System Detailed Specification

Significant Specifications and Standards:

- MIL-F-8785 Flying Qualities Piloted Airplanes
- MIL-F-9490 Flight Control Systems - Design, Installation and Testing of Piloted Aircraft, General Specification for
- MIL-H-5440 Hydraulic Systems, Aircraft Types I and II, Design, Installation, and Data Requirements for
- MIL-STD-704 Electrical Power, Aircraft, Characteristics and Utilization of
- DOD-STD-2167 Military Standard, Defense System Software Development

Notes:
1. Specifications Can be Tailored in Weapons System Detailed Specification
2. Military Specifications are Being Replaced by Industry Standards.

Carrier Based Aircraft - Unique Requirements

Navy Experience and Concerns That Drove Requirements

- Reliability History of Their Fleet
  - Electrical Wiring, Connectors and Generators
  - Electronic Systems (Autopilot, Autothrottle, etc.)
- Maintainability History - Needs Major Improvement
- Carrier Operations
  - Approach Speed
  - Catapult/Arresting Gear Loads
  - Spotting Factor (Wing Fold)
  - Environment
    - Corrosion Due to Humidity and Salt Water
    - Electromagnetic Interference
  - “Blue Water Operations” - No Alternate Field in Range
- Survivability
- First Production Digital FBW Flight Control System
  - Electromagnetic Interference
  - Generic Software Failures

F/A-18A FCS REQUIREMENTS

SD-565-1,3.3.1

"3.1.10.2 With mechanical pitch and roll controls only, and with no less than two like failures in the rudder control system, the aircraft shall be capable of returning and performing a field landing. Categories B and C, Level 3 longitudinal short-period and Dutch roll frequencies, time-to-bank, and cross wind requirements shall be met."

SD-565-1, Appendix G.

"4.3.37 The flight control system shall incorporate design features to minimize loss of flight path control due to single hits form a 23 mm HEI-T or specified fragment. Routing and separation of electrical signal wiring and mechanical flight control systems shall be such that maximum protection against 23 mm HEI-T or specified fragment is afforded by masking and/or shielding."

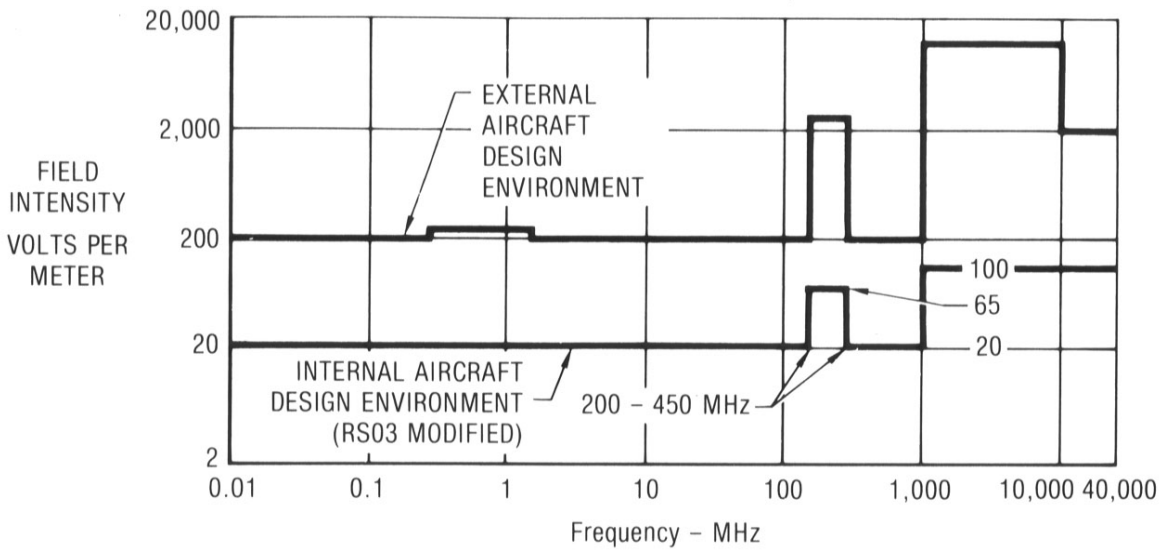
MIL-H-5440F, 3.2

". . . The hydraulic system(s) shall be configured such that any two fluid system failures due to combat or other damage which cause loss of fluid or pressure will not result in complete loss of flight control . . ."

AS1291 (AV), 3.7.68

"b. Ability to withstand one electronic failure and continue to provide Level 1 performance as defined in MIL-F-8785. With two like electronic failures, the flight control system shall provide Level 3 performance.

ELECTROMAGNETIC ENVIRONMENT COMPATIBILITY



Design Approach:

- Use Airframe As Electromagnetic Shield (Carbon/epoxy)
- Antenna EM Radiation Control
- Subsystem EM Control: Bonding, Twisted/Shielded Wiring, Filter Pin Connectors
- Ground Plane Interface Requirements

Discussion of Requirements

F/A-18A Hornet

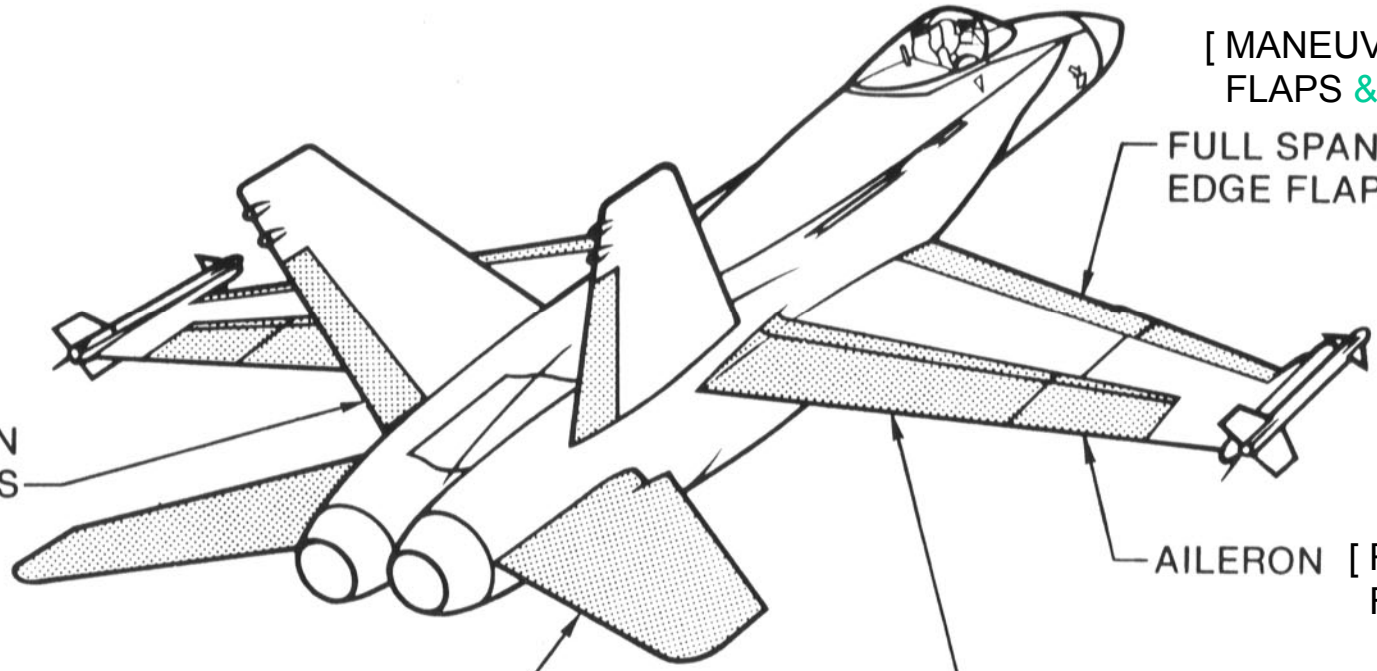
Primary Flight Control System

Quad Digital FBW

- **Ailerons**
- **Rudders**
- **Leading Edge Flaps**
- **Trailing Edge Flaps**
- **Stabilators - With Mechanical Back-up**

WHY DID THEY DO THAT ?

CONTROL SURFACES



[MANEUVERING FLAPS & ROLL]

FULL SPAN LEADING EDGE FLAP

TWIN RUDDERS

[YAW & PITCH]

AILERON [ROLL & FLAPS]

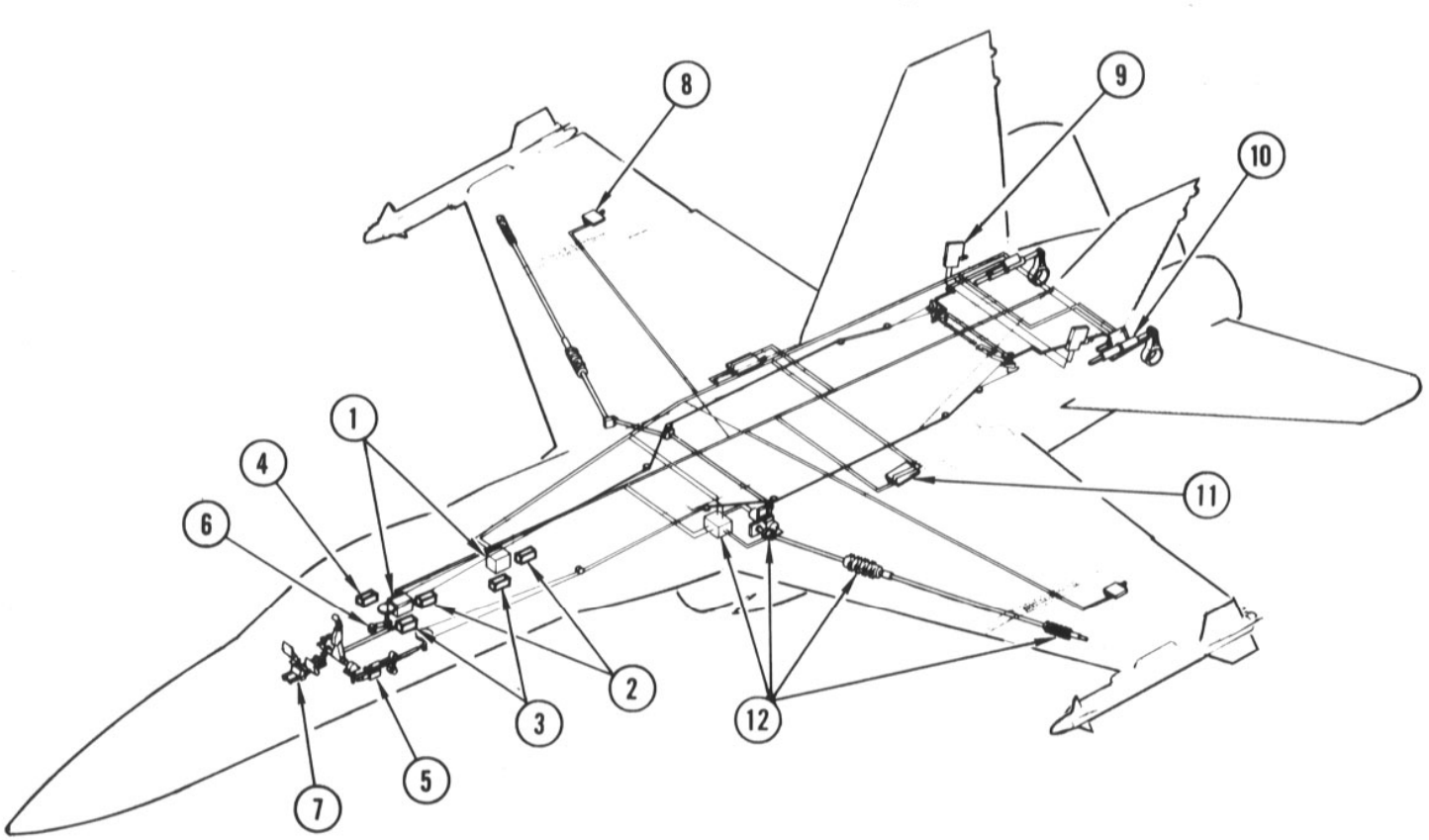
TRAILING EDGE FLAP

[MANEUVERING FLAPS & ROLL]

STABILATOR

[PITCH & ROLL]

F/A-18A Flight Control System



1. Flight Control Computers
2. Rate Gyros
3. Accelerometers
4. Backup Air Data Sensor Assembly
5. Pitch Stick Position Sensor/Feel Spring
6. Roll Stick Position Sensor/Feel Spring
7. Rudder Pedal Force Sensor
8. Aileron Actuator
9. Rudder Actuator
10. Stabilator Actuator
11. Trailing Edge Flap Actuator
12. Leading Edge Flap Actuation System
    - Hydraulic Drive Unit
    - Servovalve Assembly
    - Asymmetry Sensor

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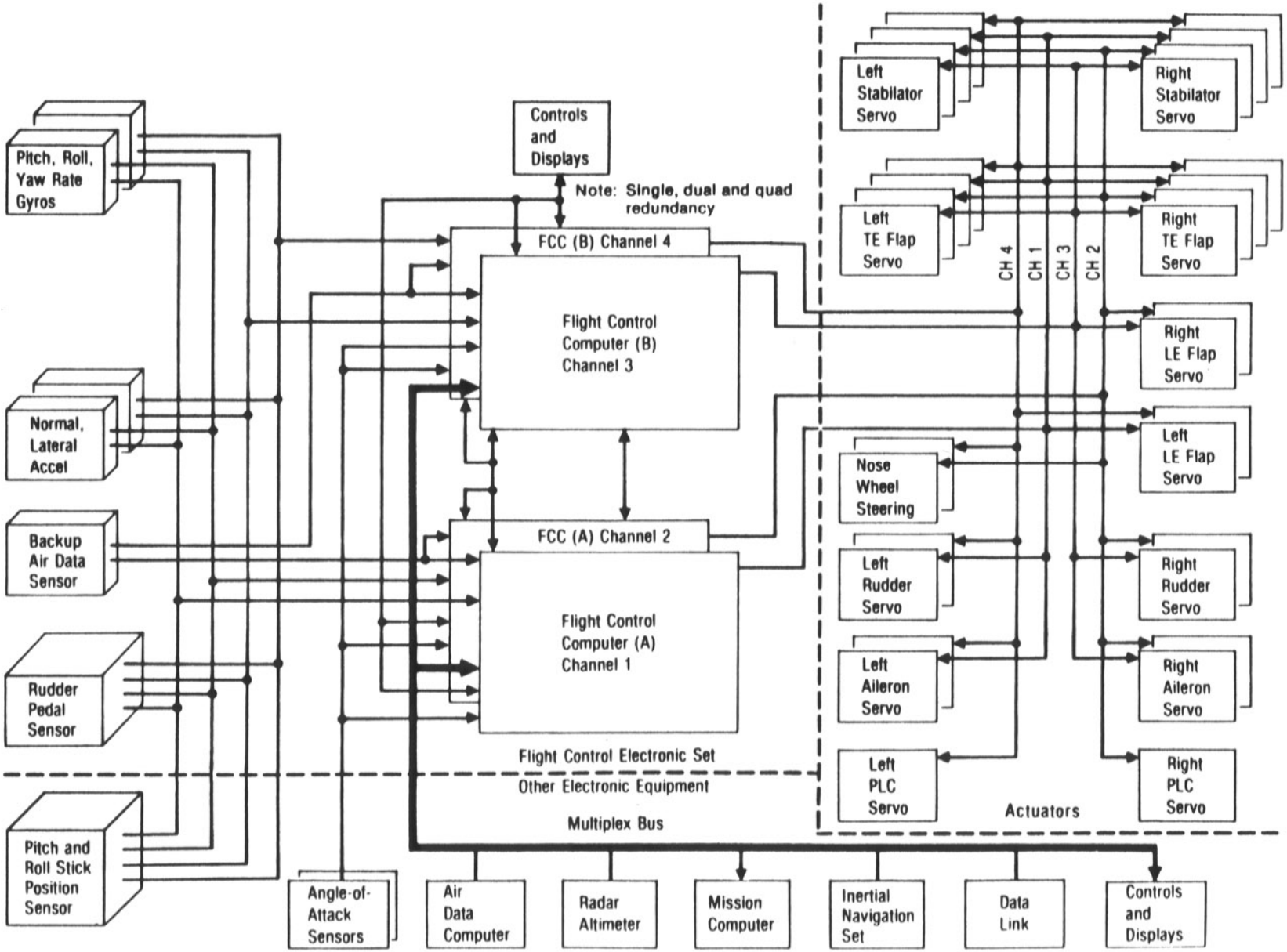
F/A-18A Flight Control System Redundancy Levels

- Redundancy Levels Driven By Reliability and Survivability
- Control Functions Critical to Flying Qualities and/or Safety Must Have Two-Fail-Operate/Fail-Safe Capability
  - Primary Control Commands
  - Motion Sensors
  - Stabilator Actuators
  - Trailing Edge Flap Actuators (Needed for Carrier Landing)
- Control Surfaces with Aerodynamic Redundancy and Less Critical Functions Must Have Fail-Operate/Fail-Safe Capability
- Survivability Protection Dictated Separation of Control Functions
  - Flight Control Computers
  - Motion Sensors
  - Interconnecting Wiring

FLIGHT CONTROL ELECTRONIC SET INTERFACE



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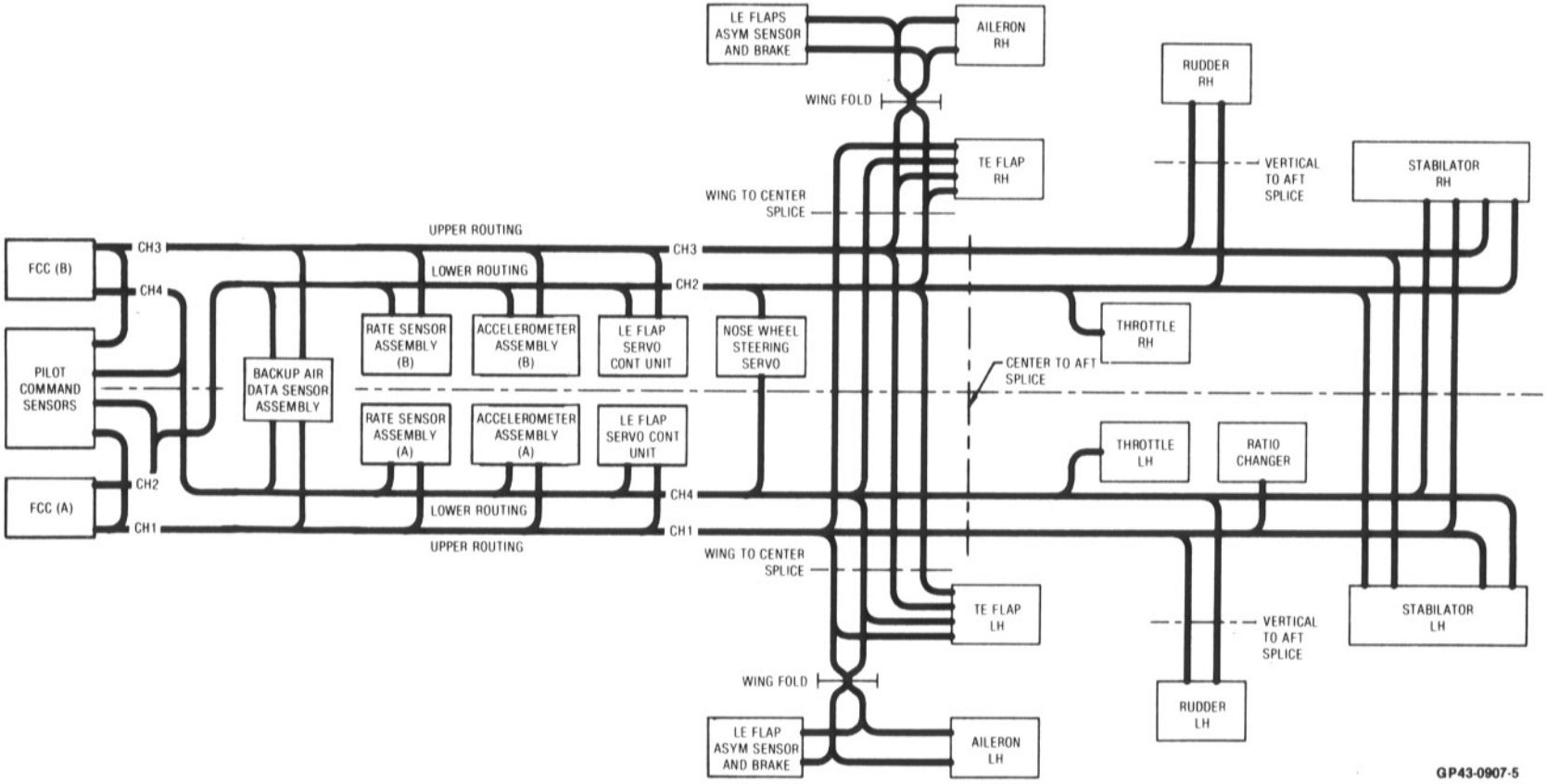
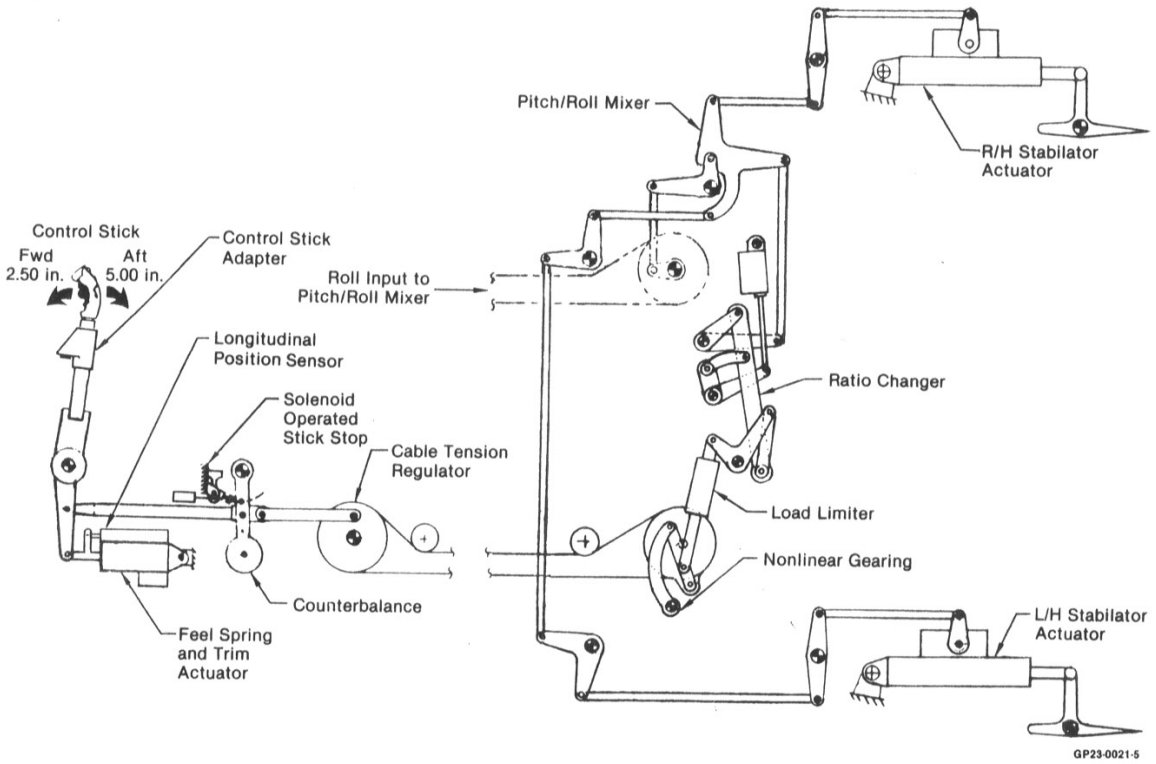
FLIGHT CONTROL CHANNEL ARRANGEMENT



Longitudinal Control System Schematic



REVERSION TO BACKUP MODES

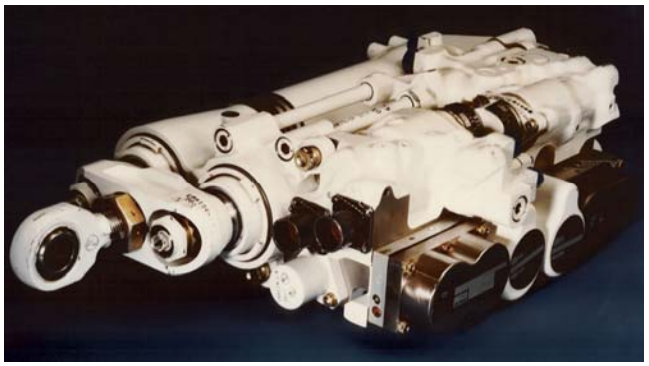
BACKUP MODES	FAILURES CAUSING REVERSION	PROBABILITY OF REVERSION
MECHANICAL	THIRD PITCH OR ROLL CONTROL STICK SENSOR	3.2×10^{-14} PER 2 HR FLIGHT
	THIRD DIGITAL PROCESSOR	9.7×10^{-10} PER 2 HR FLIGHT
	THIRD COMPUTER POWER SUPPLY	1.6×10^{-9} PER 2 HR FLIGHT
	THIRD STABILATOR ACTUATOR SERVO LOOP	7.7×10^{-7} PER 2 HR FLIGHT
ANALOG DEL	THIRD DIGITAL PROCESSOR	9.7×10^{-10} PER 2 HR FLIGHT

Electronic Set

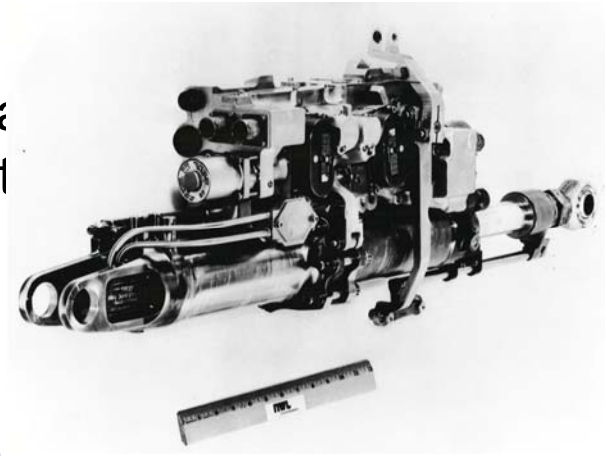
T.E. Flap Actuator

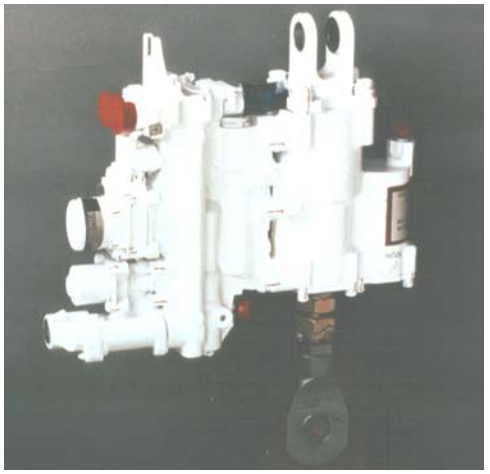
Aileron Actuator

F/A-18A Flight Control Hardware



Stabila
Actuat





Rudder
Actuator