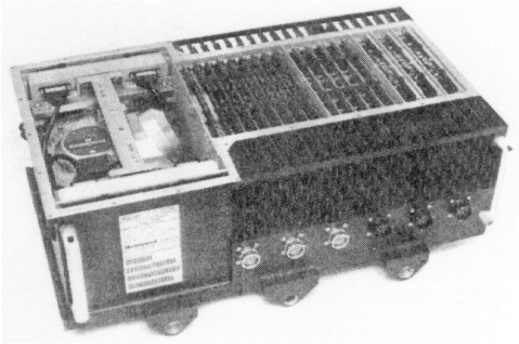
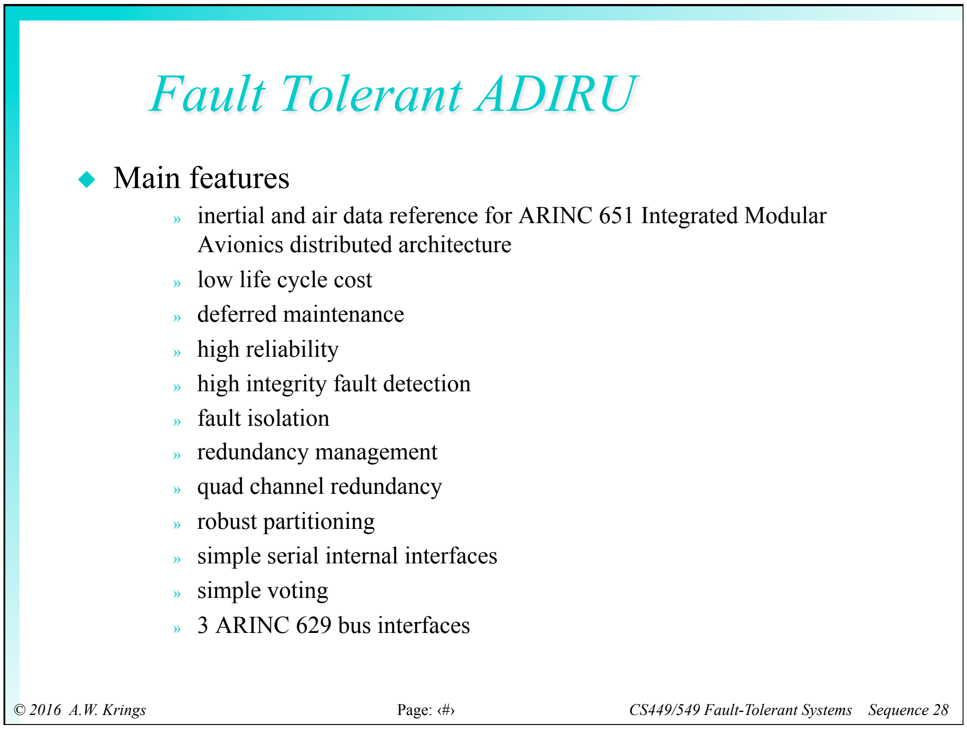
Fault Tolerant ADIRU

- The Boeing 777 has two inertia units,
  - the ADIRU (Air Data Inertial Reference Unit) and
  - the SAARU (Secondary Attitude and Arial Data Reference Unit)
- We will look at the ADIRU, based on the discussion in the paper
  - A Fault-Tolerant Air Data/Inertial Reference Unit
    - Michael L. Sheffels
    - IEEE AES Systems Magazine, March 1993

Fault Tolerant ADIRU

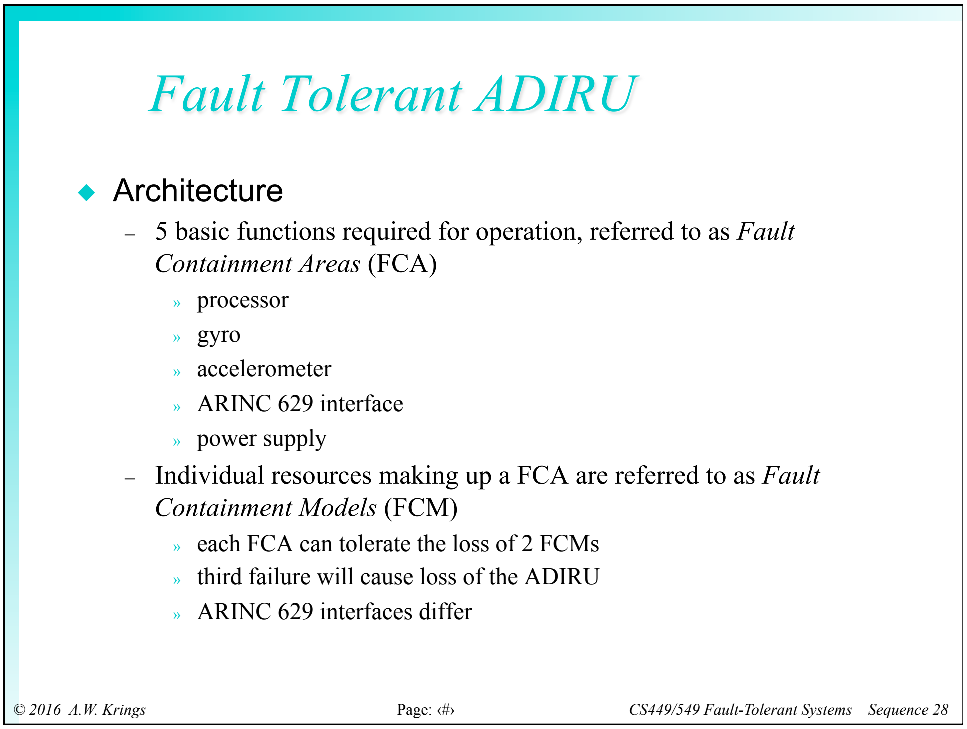
- Air Data/Inertial Reference Unit
  - ADIRU production unit





Fault Tolerant ADIRU

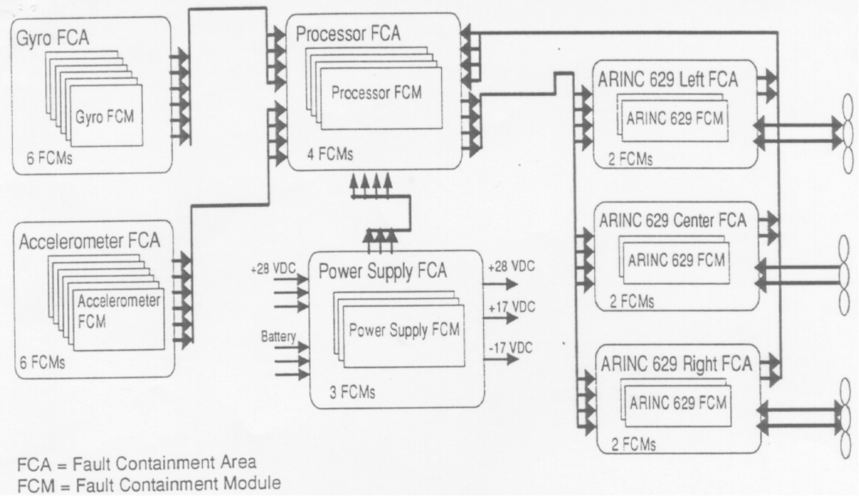
- Main features
  - » inertial and air data reference for ARINC 651 Integrated Modular Avionics distributed architecture
  - » low life cycle cost
  - » deferred maintenance
  - » high reliability
  - » high integrity fault detection
  - » fault isolation
  - » redundancy management
  - » quad channel redundancy
  - » robust partitioning
  - » simple serial internal interfaces
  - » simple voting
  - » 3 ARINC 629 bus interfaces



Fault Tolerant ADIRU

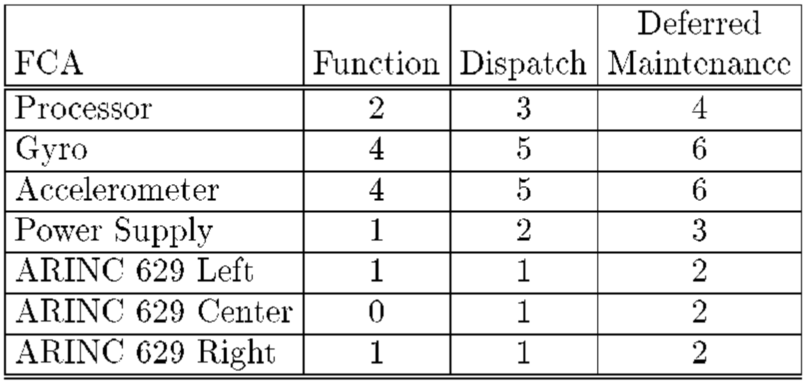
- Architecture
  - – 5 basic functions required for operation, referred to as *Fault Containment Areas* (FCA)
    - » processor
    - » gyro
    - » accelerometer
    - » ARINC 629 interface
    - » power supply
  - – Individual resources making up a FCA are referred to as *Fault Containment Models* (FCM)
    - » each FCA can tolerate the loss of 2 FCMs
    - » third failure will cause loss of the ADIRU
    - » ARINC 629 interfaces differ

Fault Tolerant ADIRU

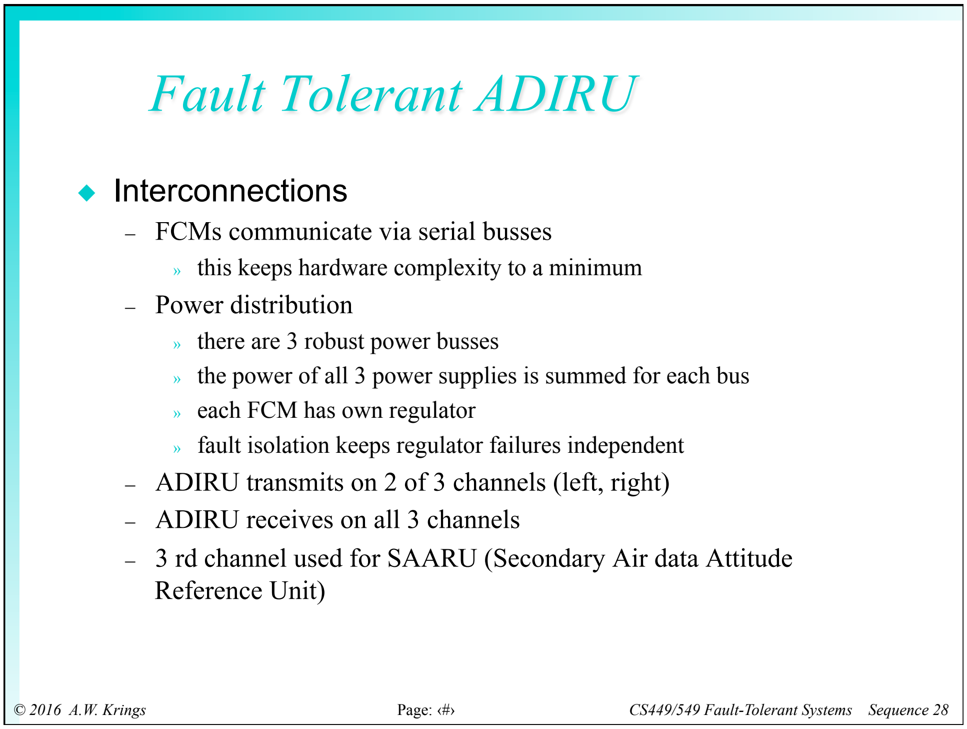


Fault Tolerant ADIRU

- Requirements

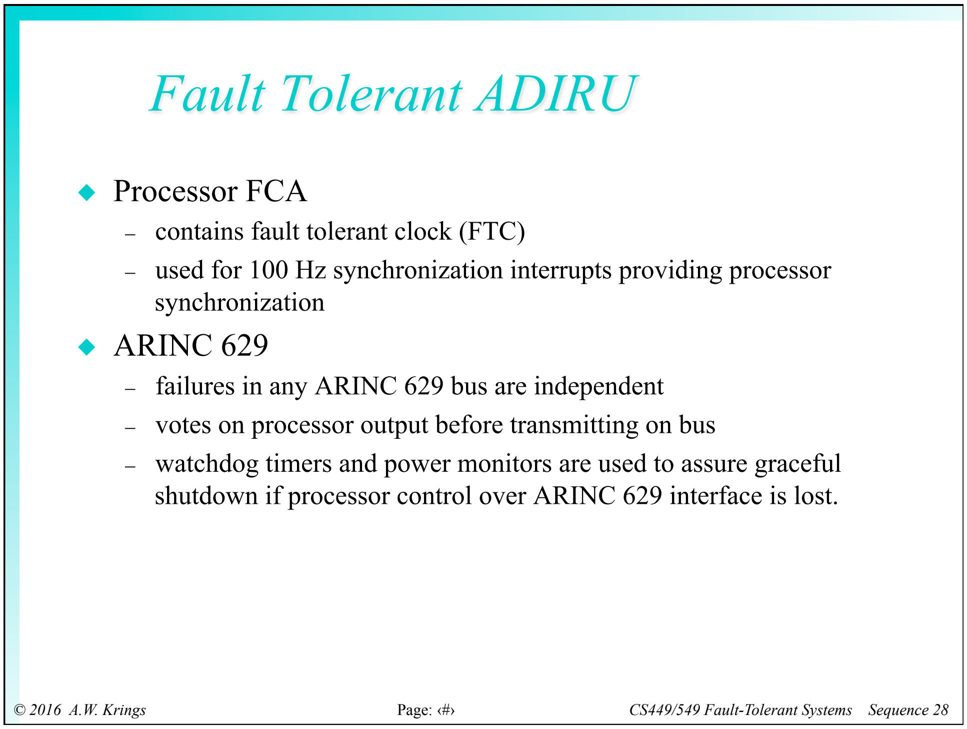


FCA	Function	Dispatch	Deferred Maintenance
Processor	2	3	4
Gyro	4	5	6
Accelerometer	4	5	6
Power Supply	1	2	3
ARINC 629 Left	1	1	2
ARINC 629 Center	0	1	2
ARINC 629 Right	1	1	2



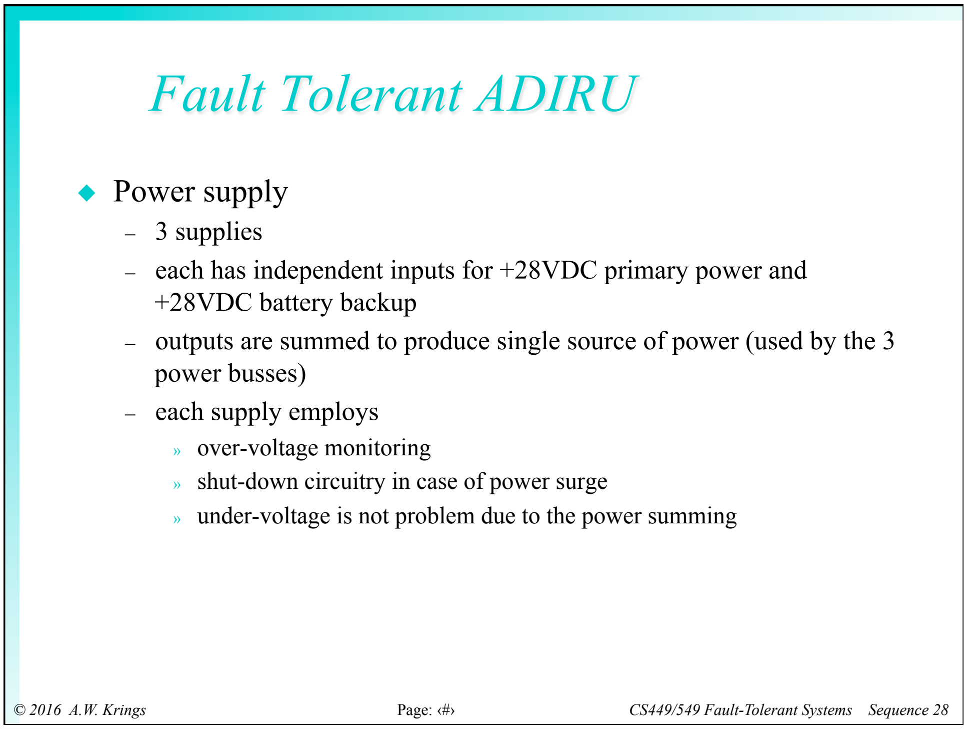
Fault Tolerant ADIRU

- Interconnections
  - FCMs communicate via serial busses
    - this keeps hardware complexity to a minimum
  - Power distribution
    - there are 3 robust power busses
    - the power of all 3 power supplies is summed for each bus
    - each FCM has own regulator
    - fault isolation keeps regulator failures independent
  - ADIRU transmits on 2 of 3 channels (left, right)
  - ADIRU receives on all 3 channels
  - 3 rd channel used for SAARU (Secondary Air data Attitude Reference Unit)



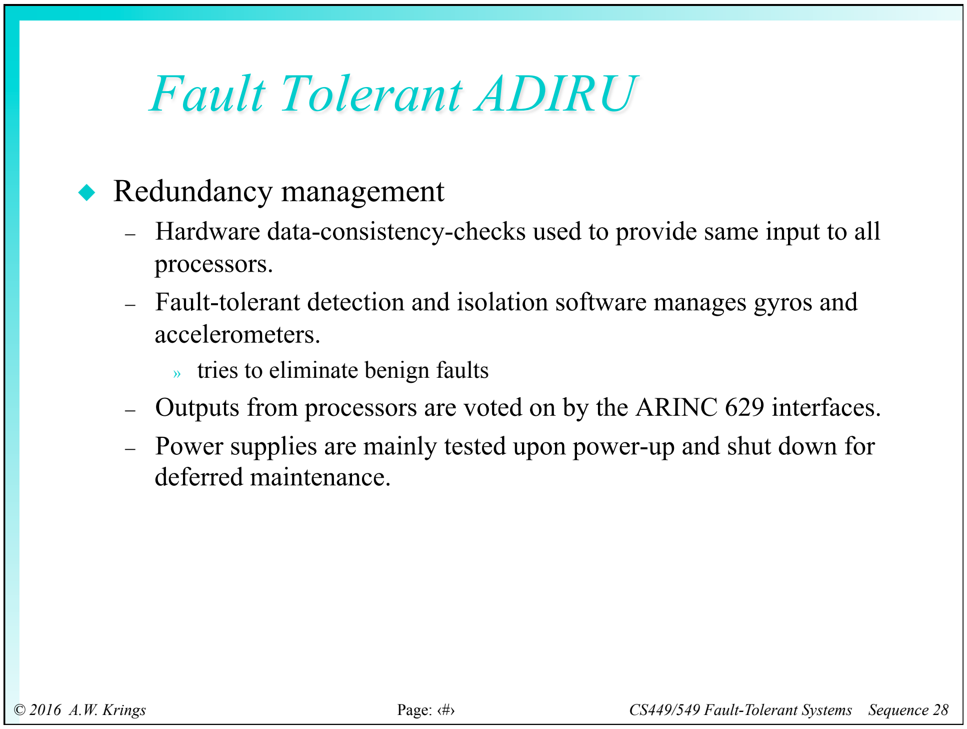
Fault Tolerant ADIRU

- Processor FCA
  - contains fault tolerant clock (FTC)
  - used for 100 Hz synchronization interrupts providing processor synchronization
- ARINC 629
  - failures in any ARINC 629 bus are independent
  - votes on processor output before transmitting on bus
  - watchdog timers and power monitors are used to assure graceful shutdown if processor control over ARINC 629 interface is lost.



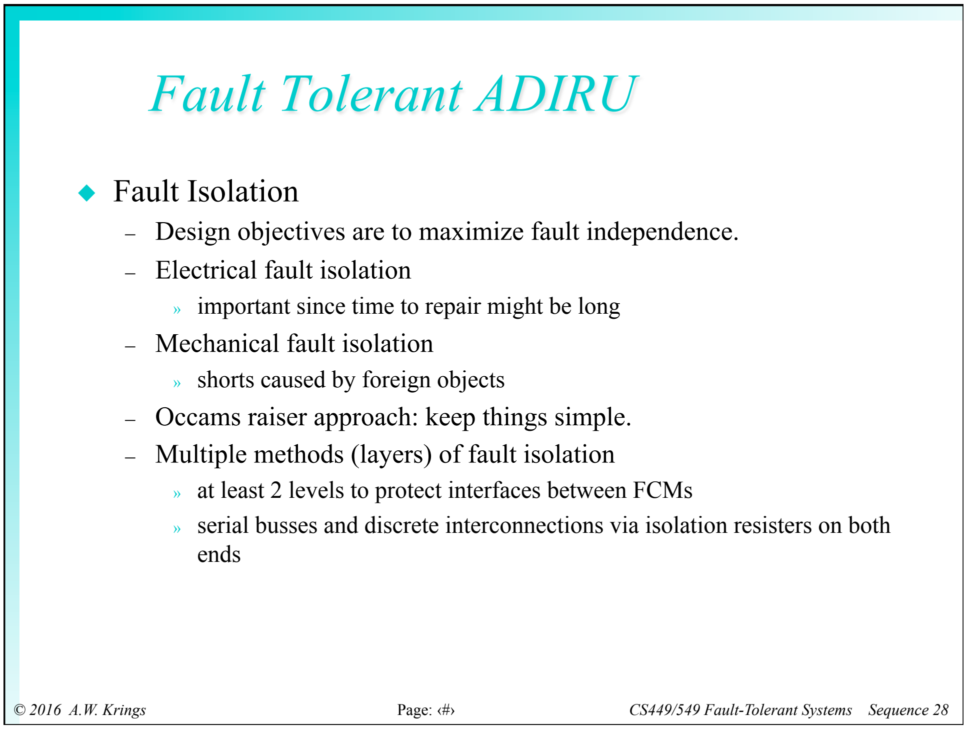
Fault Tolerant ADIRU

- Power supply
  - 3 supplies
  - each has independent inputs for +28VDC primary power and +28VDC battery backup
  - outputs are summed to produce single source of power (used by the 3 power busses)
  - each supply employs
    - over-voltage monitoring
    - shut-down circuitry in case of power surge
    - under-voltage is not problem due to the power summing



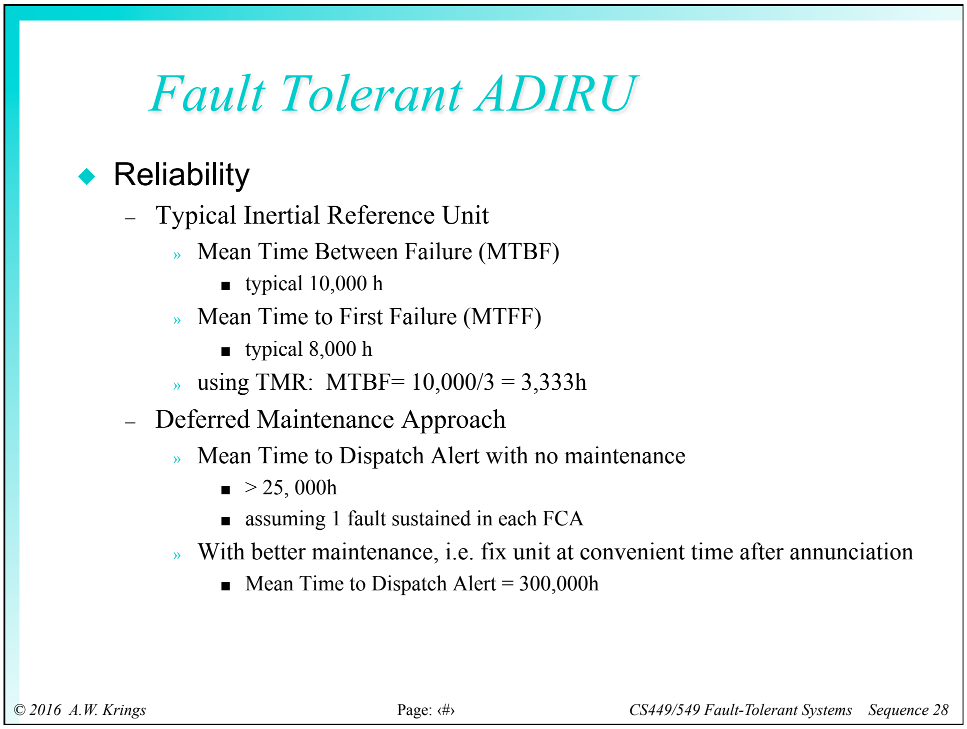
Fault Tolerant ADIRU

- Redundancy management
  - Hardware data-consistency-checks used to provide same input to all processors.
  - Fault-tolerant detection and isolation software manages gyros and accelerometers.
    - tries to eliminate benign faults
  - Outputs from processors are voted on by the ARINC 629 interfaces.
  - Power supplies are mainly tested upon power-up and shut down for deferred maintenance.



Fault Tolerant ADIRU

- Fault Isolation
  - Design objectives are to maximize fault independence.
  - Electrical fault isolation
    - important since time to repair might be long
  - Mechanical fault isolation
    - shorts caused by foreign objects
  - Occams raiser approach: keep things simple.
  - Multiple methods (layers) of fault isolation
    - at least 2 levels to protect interfaces between FCMs
    - serial busses and discrete interconnections via isolation resisters on both ends



Fault Tolerant ADIRU

- Reliability
  - Typical Inertial Reference Unit
    - Mean Time Between Failure (MTBF)
      - typical 10,000 h
    - Mean Time to First Failure (MTFF)
      - typical 8,000 h
    - using TMR: MTBF= 10,000/3 = 3,333h
  - Deferred Maintenance Approach
    - Mean Time to Dispatch Alert with no maintenance
      - > 25, 000h
      - assuming 1 fault sustained in each FCA
    - With better maintenance, i.e. fix unit at convenient time after annunciation
      - Mean Time to Dispatch Alert = 300,000h