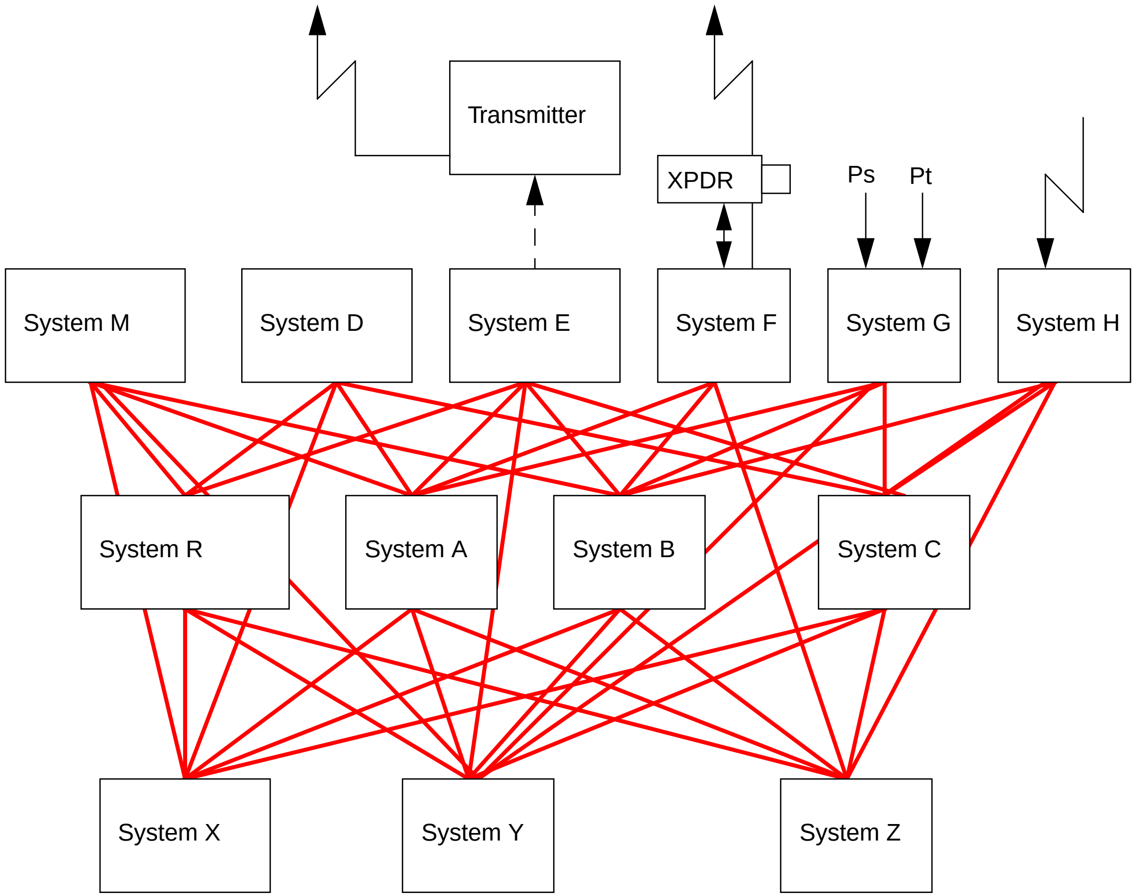
Fly-By-Wire for Experimental Aircraft?

A Vision based on CANaerospace/AGATE Data Bus Technology

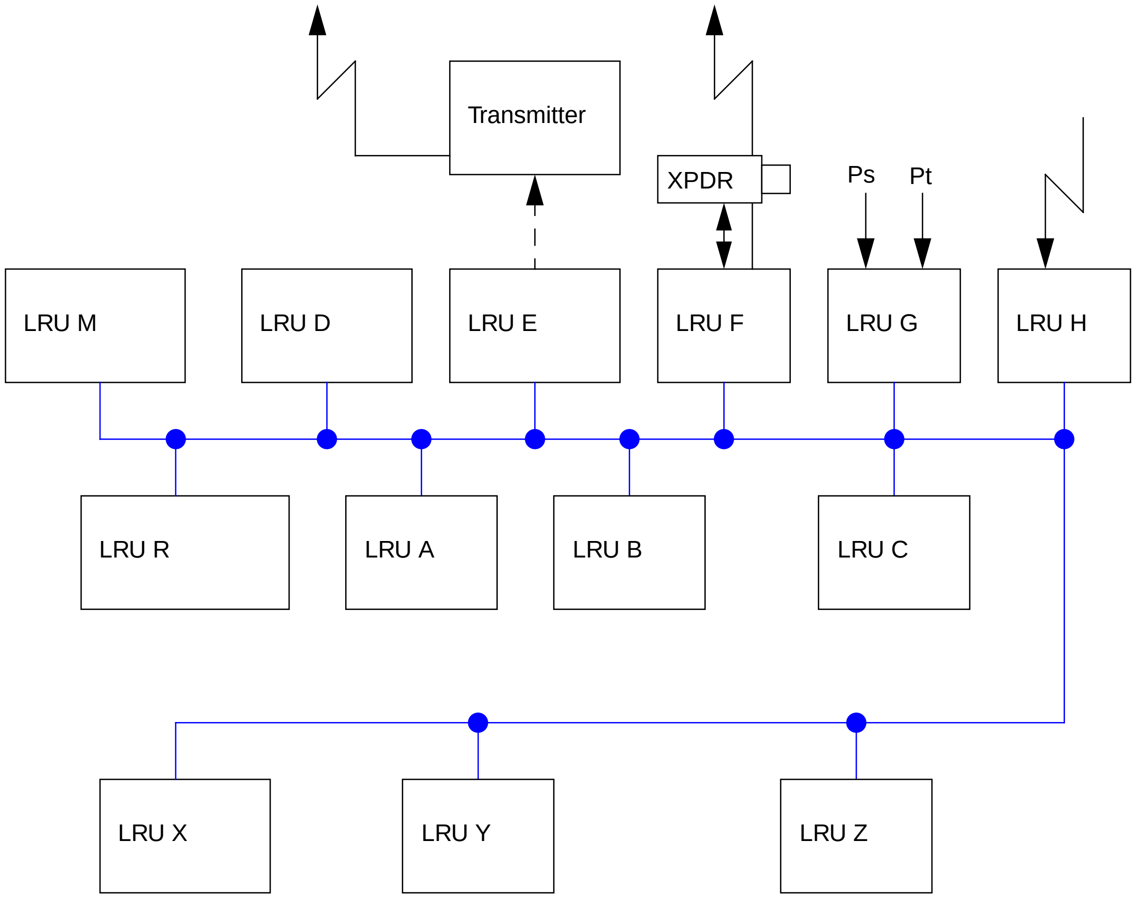
Driven by CAN Aerospace

Traditional Avionics System



- Numerous dedicated connections
- Numerous different interfaces (analog, discrete, RS-232, ...)
- Functional incompatibility problems (subsystems not talking the same “language”)
- Difficult component selection
- Complex and heavy wire bundles
- Signal and connector incompatibility problems
- Difficult airplane integration, troubleshooting and maintenance

Integrated Modular Avionics (IMA) System



- Central communication network
- Standardized communication protocol and interface components
- Significant reduction in complexity and weight of the wire harness
- Improved reliability (less connectors)
- Built-in test and maintenance functions
- Line Replaceable Units (LRU) with comparable functionality from different vendors can be exchanged

Controller Area Network (CAN) Data Bus

- Two-wire multi-transmitter serial data bus standard
- Designed by Bosch in 1983 as automotive network
- No central bus controller required
- Configurable data rate (83.3 kbit/s ... 1 Mbit/s)
- Maximum bus length at 1 Mbit/s: 40m (120 ft.)
- Data object oriented transmission based on message identifiers
- Broadcast transmission ensures network wide data consistency
- No overhead for bus arbitration
- Extremely low probability of undetected data corruption
- More than 500 million nodes installed to date
- Very low chip cost for controllers and transceivers (< $5 per node)
- Simple application programming (chip resident communication protocol)

CANaerospace as Link between CAN and Application Software

Application Software

layer 7 (application layer)	set of user-defined application functions
layer 6 (presentation layer)	data representation, data standardization, ...
layer 5 (session layer)	login, session dialog control, ...
layer 4 (transport layer)	logical channels, data transmission retries, ...
layer 3 (network layer)	routing, data packet flow control, ...
layer 2 (data link layer)	error detection, data block synchronisation, ...
layer 1 (physical layer)	connectors, cables, voltage levels, ...

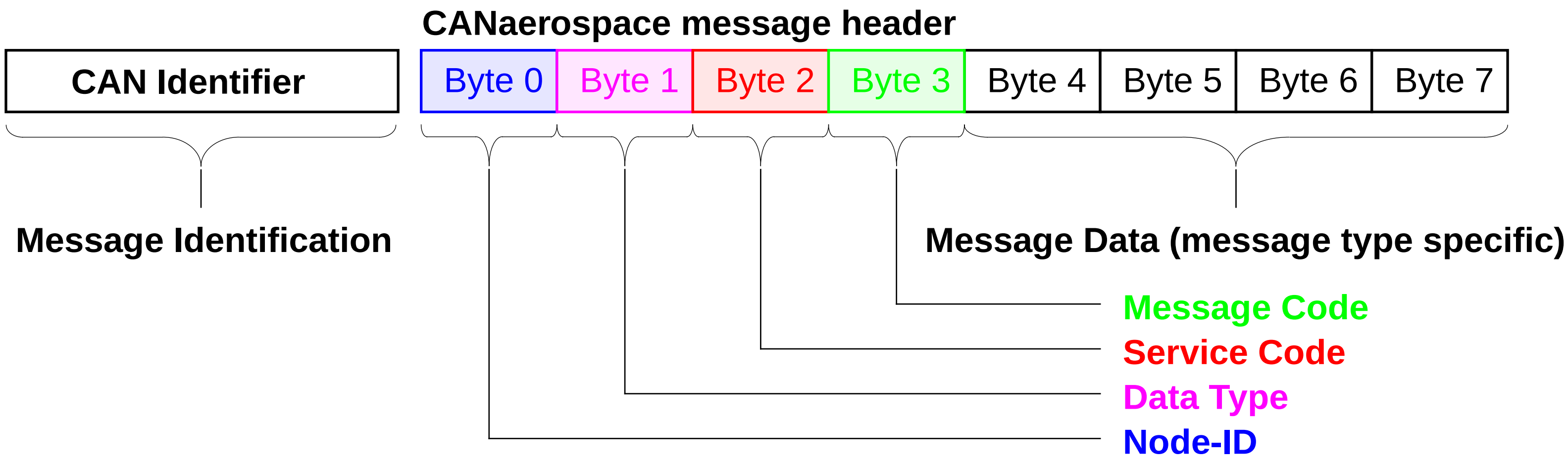
CANaerospace (AGATE Data Bus): layers 7 – 3

CAN: layers 2 – 1

CAN

CANaerospace Message Format

- The CAN specification does not cover topics like data representation, station addressing or peer-to-peer communication
- CANaerospace is an interface specification that closes this gap and turns CAN into an IMA network suitable for mission and safety critical systems
- The message payload receives a CANaerospace-specific structure
- A peer-to-peer communication mechanism supports test and maintenance functions
- The CAN Identifier is used to standardize the communication between LRUs

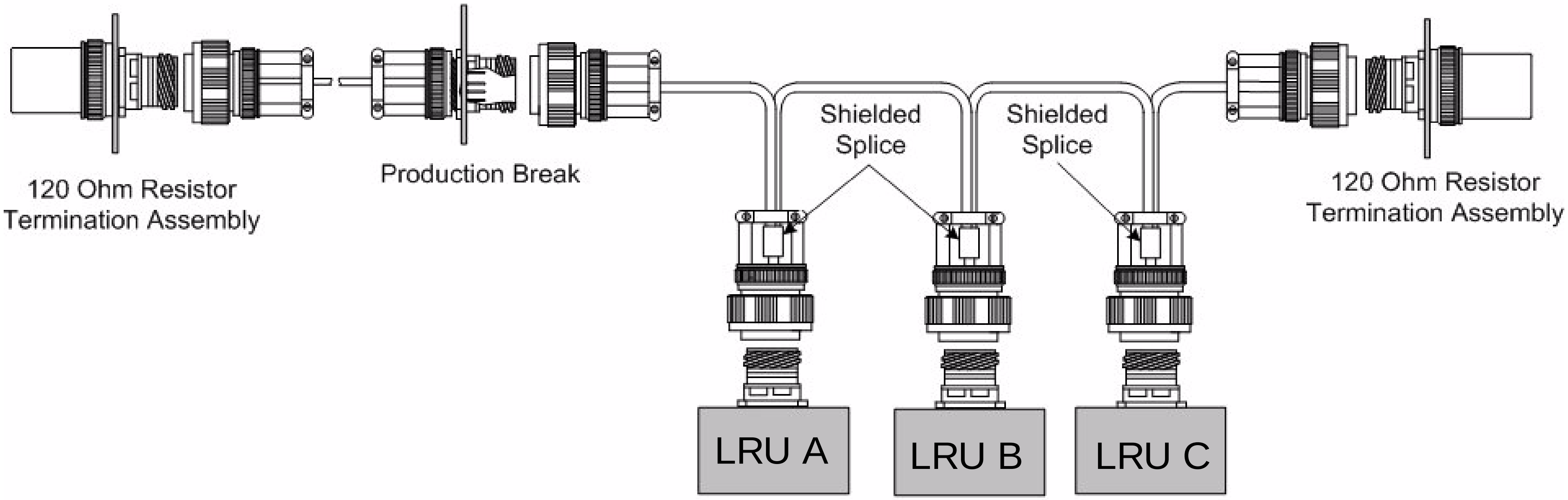


CANaerospace Message Standardization Examples

CAN Identifier	System Parameter Name	Data Type	Unit	Notes
317	Calibrated Airspeed	FLOAT SHORT2	m/s	
321	Heading Angle	FLOAT SHORT2	deg	+/-180^o
401	Roll Control Position	FLOAT SHORT2	%	Right: + Left: -
500	Engine #1 N1 ECS Channel A	FLOAT SHORT2	1/min	N1 for jet, RPM for Pi-ston Engines
1008	Active Nav System Track Er-ror Angle (TKE)	FLOAT SHORT2	deg	Service Code Field Contains Waypoint #
1070	Radio Height	FLOAT SHORT2	m	
1205	Lateral Center of Gravity	FLOAT SHORT2	% MAC	

CANaerospace Aircraft Network Installation

- Well defined physical layer according to ISO standard 11898
- Straight line topology with twisted pair cable and 120Ω termination resistors at both ends
- Shielded or unshielded cables may be used as well as D-Sub connectors
- LRU position in the network and distance from LRU to LRU is uncritical
- LRUs can be removed from or attached to the network without causing adverse effects



CANaerospace Application Example - SOFIA

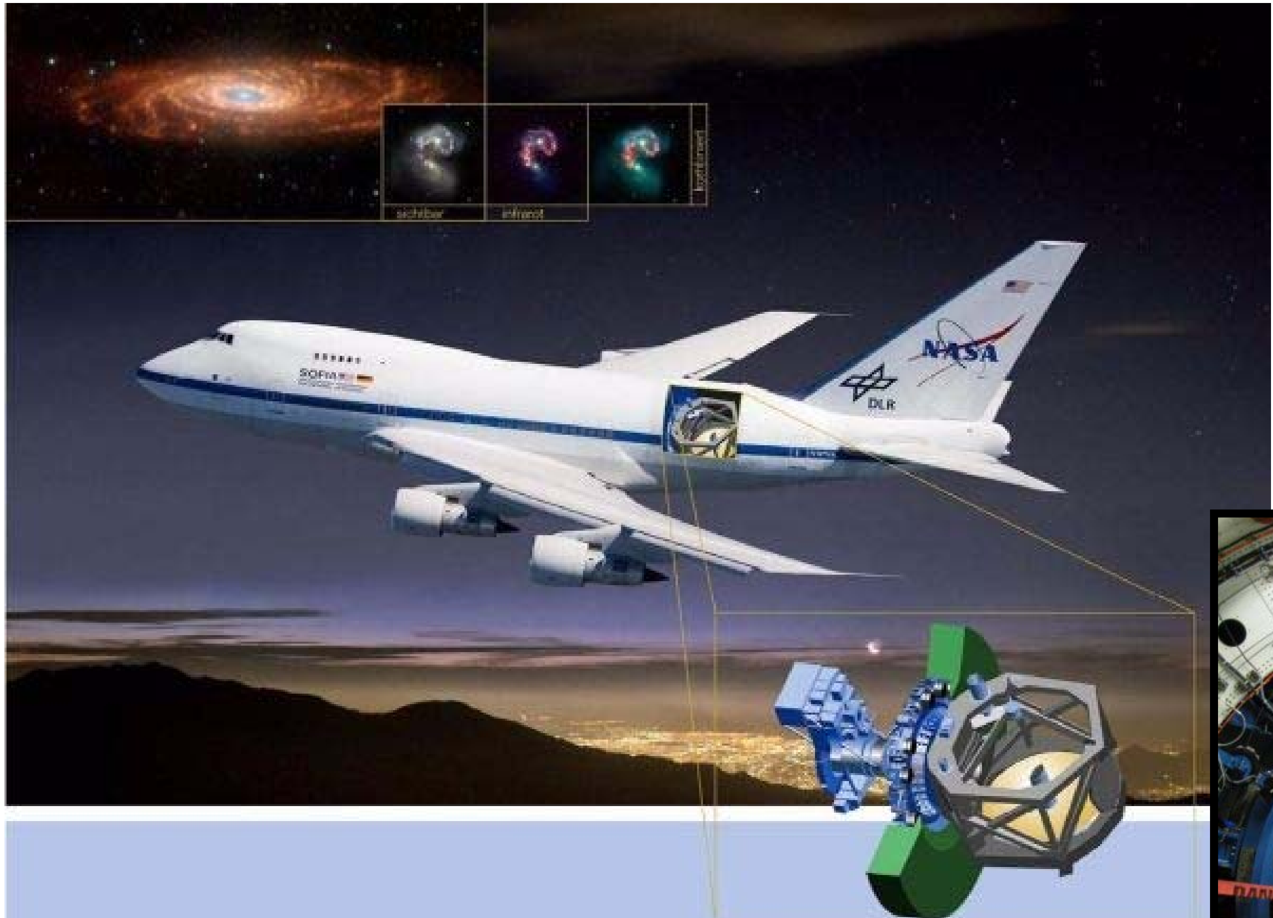


Image: Deutsches SOFIA-Institut (www.dsi.uni-stuttgart.de)

- Boeing 747SP carrying the largest airborne telescope in the world
- CANaerospace used for communication between star tracking system and numerous real time control computer systems

CANaerospace Application Example - SAM

Photo: Unis s.r.o. (www.unis.cz)

- The System of Aviation Modules (SAM) has successfully passed FAA Part 23 certification. SAM comprises of seven intelligent units which communicate using CANaerospace.
- SAM functions include electric power supply monitoring, fuel distribution and supply control, hydraulic system control, propeller heating control, airframe load monitoring and windshield deicing.

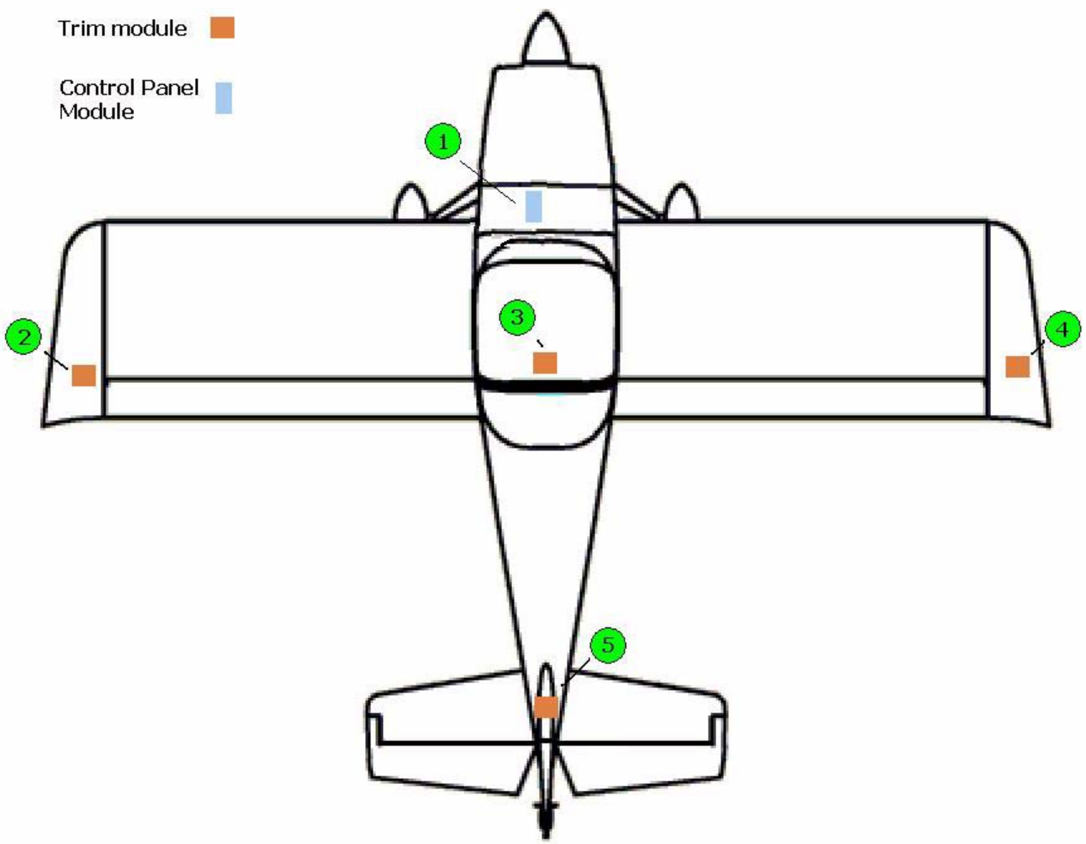
RV-7ca Integrated Modular Avionics System

- **Phase 1:** In phase one of this project, several isolated IMA modules are being tested in an existing RV-6A airframe. These IMA's control trim tabs, power distribution, flaps and include supporting systems such as non-contact angle sensors, and a 'serial stick grip' (SSG) interface. Several items have already completed their preliminary testing.

- **Phase 2:** The second phase of this project involves the installation of these devices in a new RV-7. Five IMA units will be installed as a system. They will decentralize the power distribution, simplify the wiring harness, and manage both the trim and flap systems.

- **Phase 3:** The CANaerospace system will be tested with third party devices allowing them to share the CAN bus for communications with their own proprietary sensors while maintaining their ability to monitor CANaerospace messages of interest from other CANaerospace compliant devices.

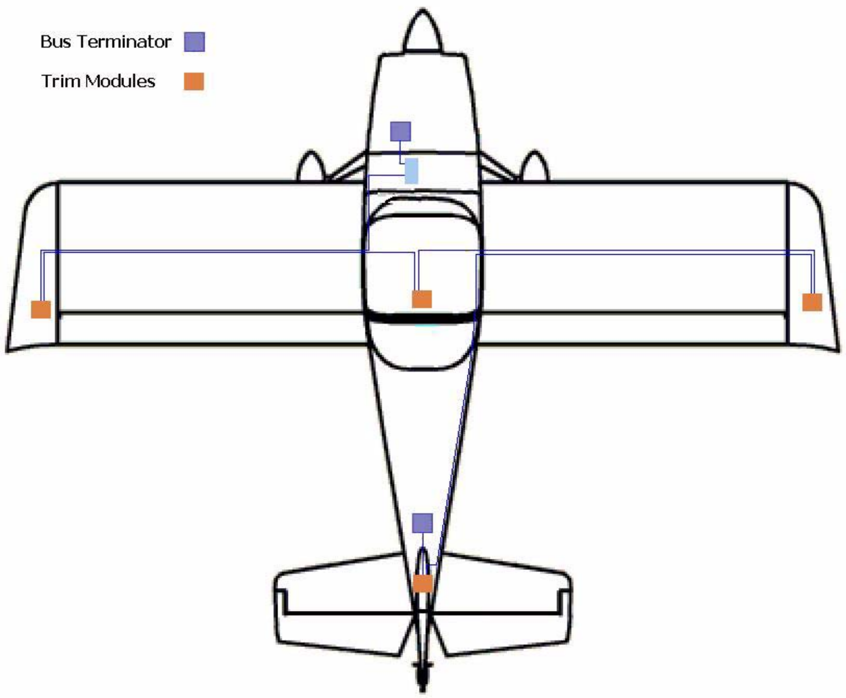
Phase 2 Module Locations and Targets



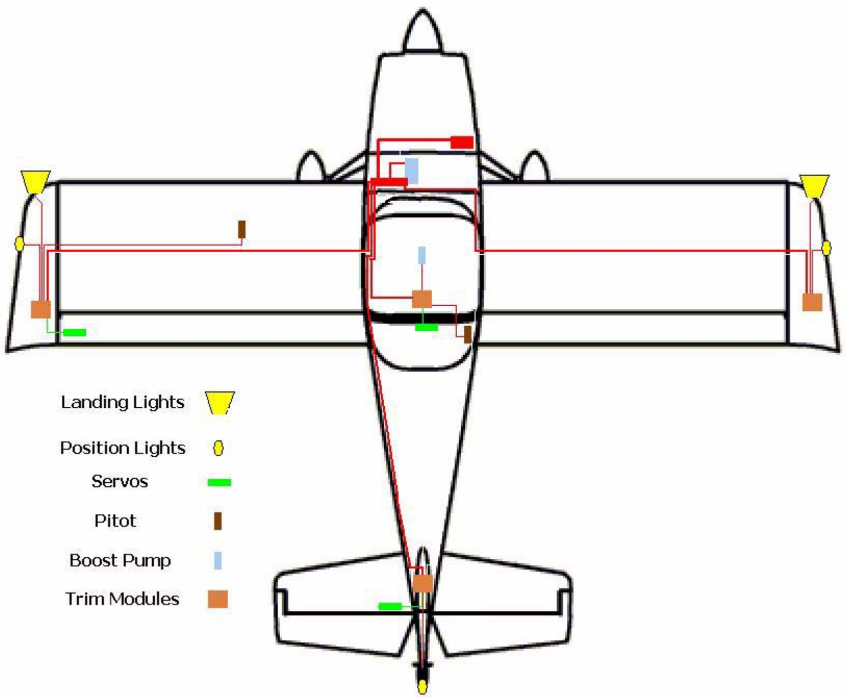
Loc	Identifier	Target
1	Control Panel	Panel Switches and Lamps, Avionics/EFIS Bridge, Starter
2	Left Wing	Landing Light, Position Light, Pitot Heater, Roll Trim
3	Cabin	Strobe, Boost Pump, Cabin Lamp, Flaps, Stick Grip
4	Right Wing	Landing Light, Position Light
5	Empennage	Position Light, Aux Lighting, Pitch Trim, GPS Bridge

RV-7ca Electrical Harness

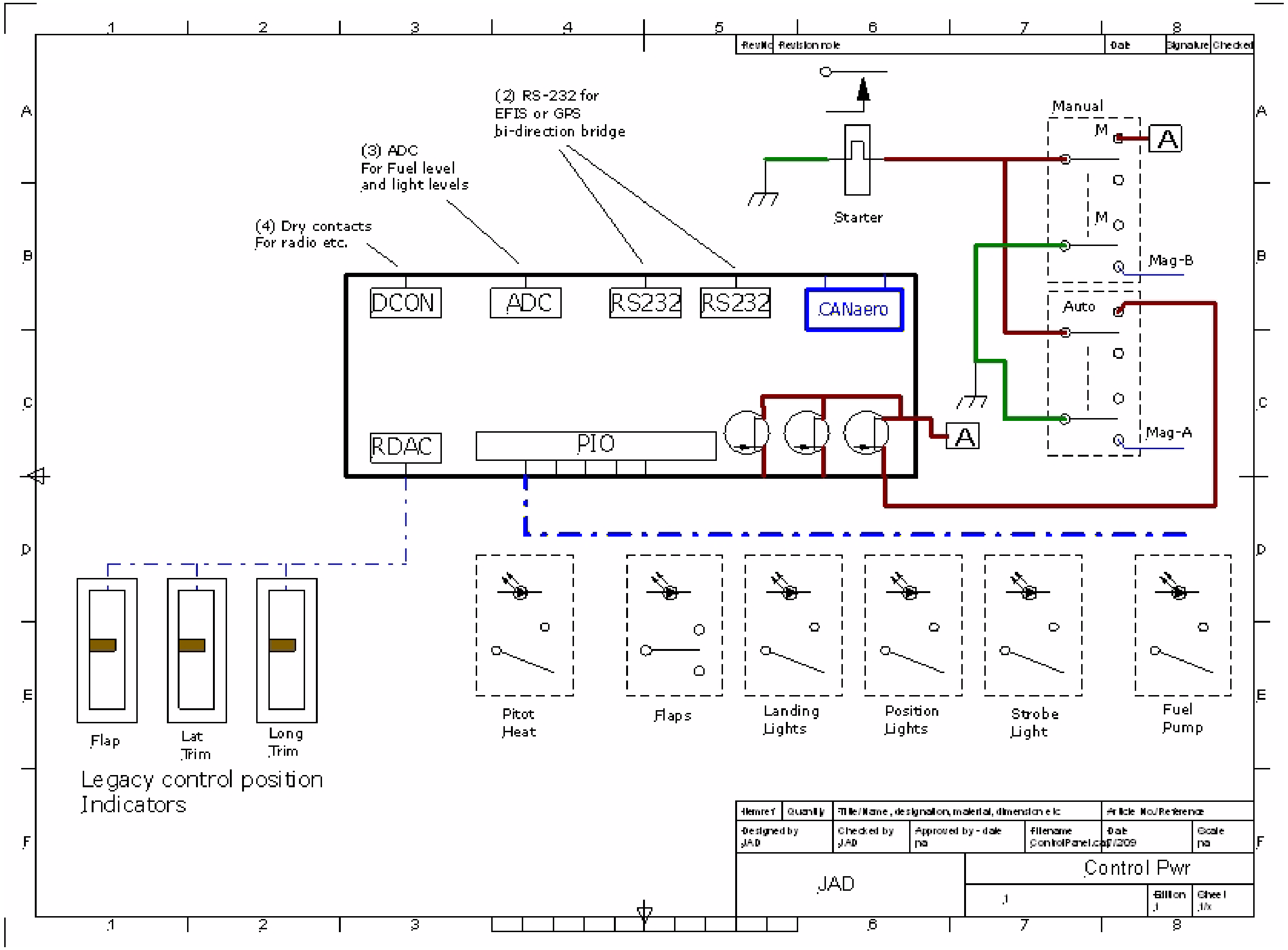
CANaerospace Bus Routing



Primary Electric Paths

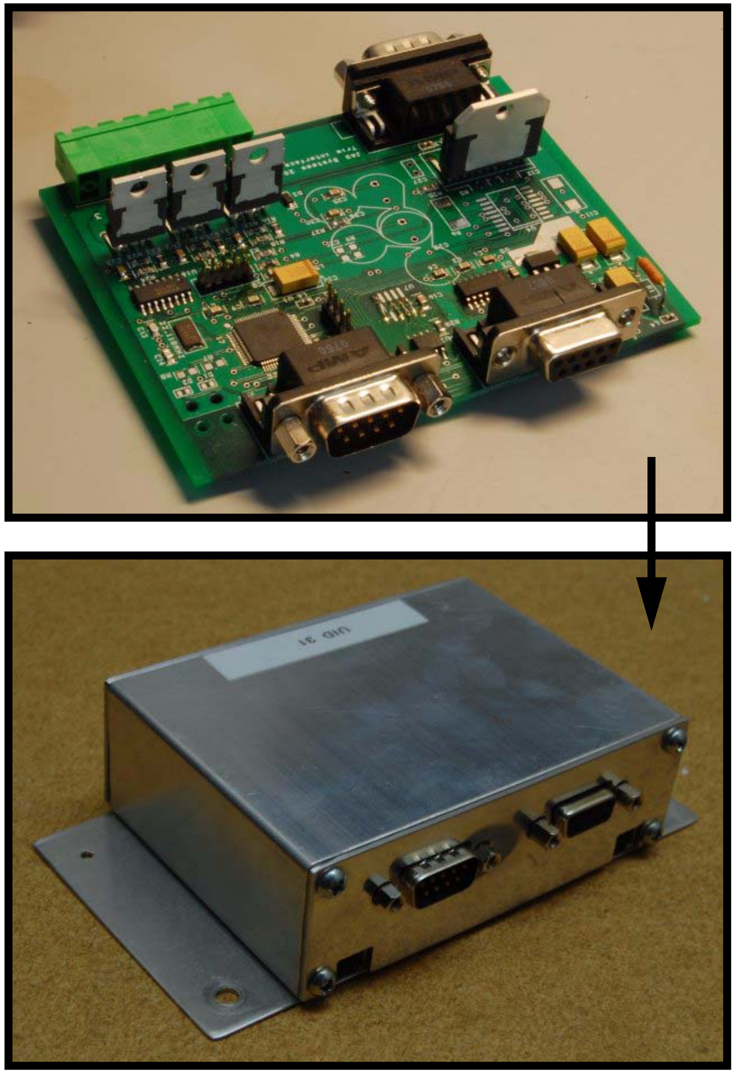


IMA Control Panel Module

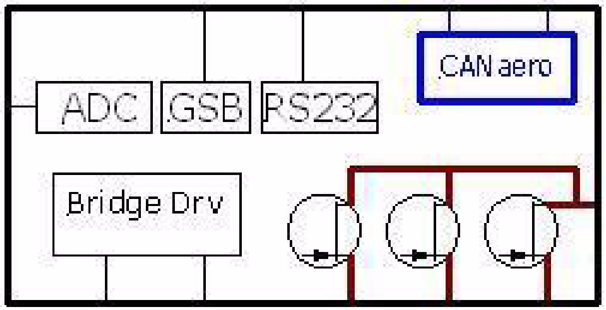


- Power drivers to control and monitor up to three 20amp loads
- Solid state altimeter (Blind Encoder)
- Two RS-232 ports
- Twelve lamp/LCD drivers
- Sixteen switch inputs
- Four dry contacts (Relays)
- Three RDAC drivers
- CAN bus interface
- Two Fuel level ADCs
- Lamp Dimmer input

IMA Trim Module



- Bridge driver and ADC I/O for local trim and flap servos
- Power drivers to control and monitor up to three 20amp loads
- Internal voltage and temperature sensor to monitor environment and source power
- CAN bus interface
- GSB interface for I2C
- RS-232 interface
- Non-contact magnetic angle sensor with +/- 45 deg. range

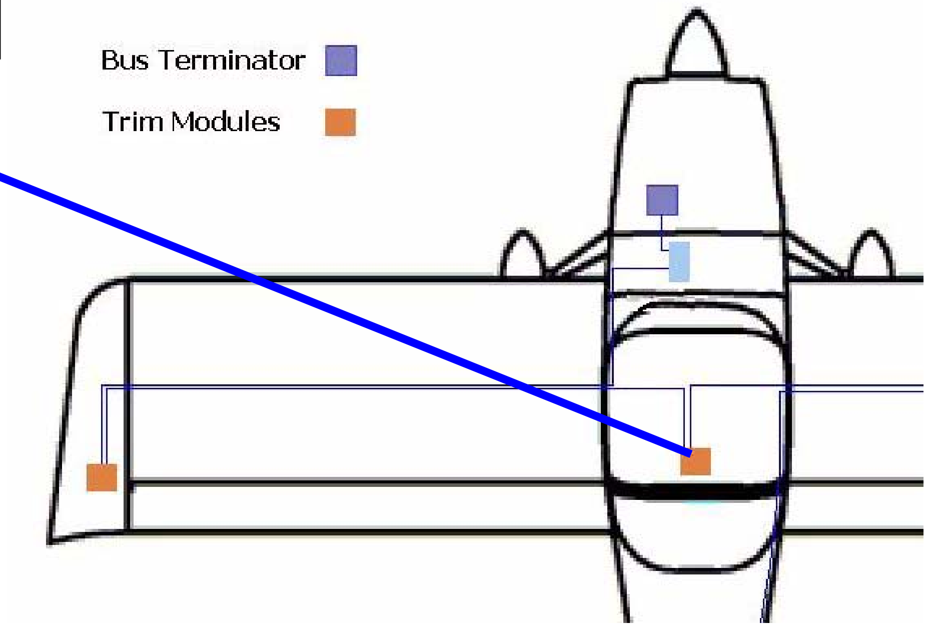


Serial Stick Grip

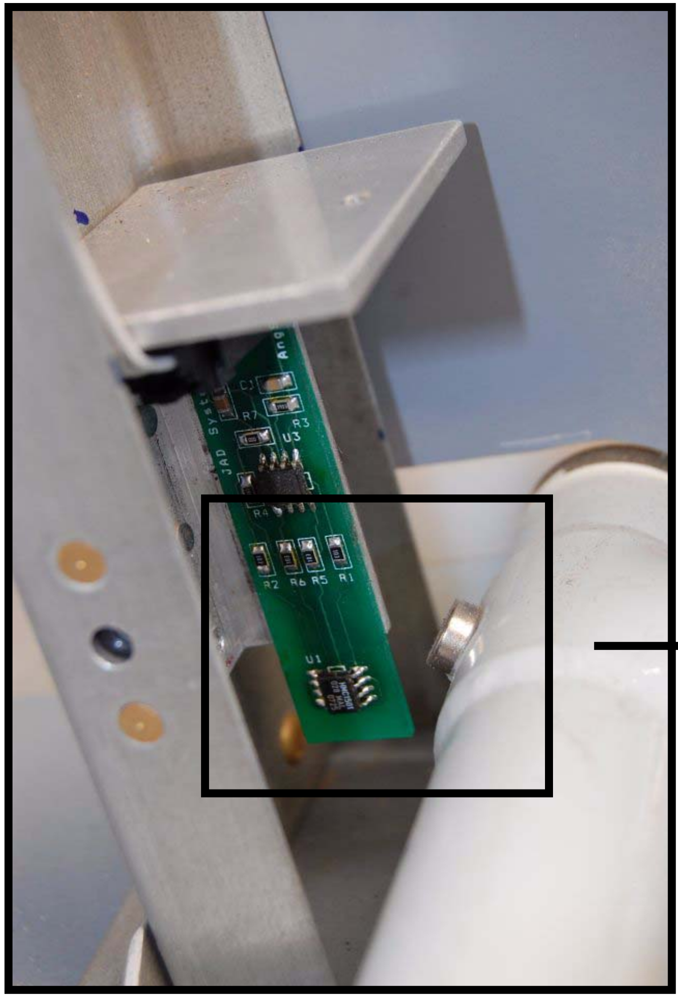
- Wire bundle reduction
- Inter-IC bus to CANaerospace conversion

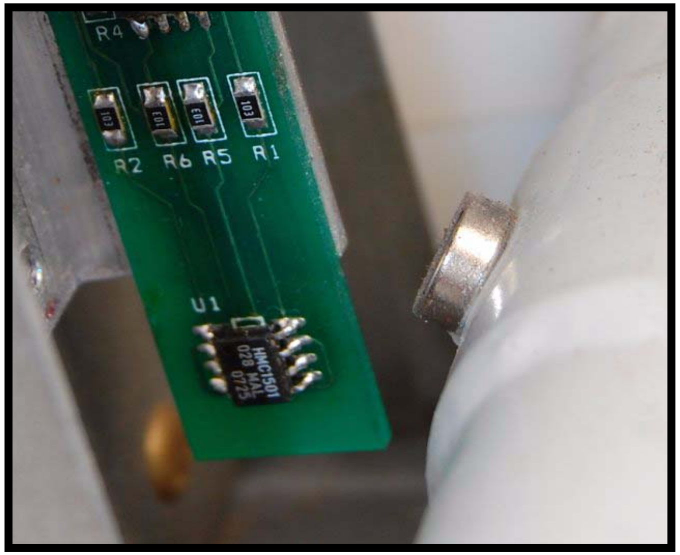
Traditional Stick Grip

Stick Grip with Serial Interface Controller



Non-Contact Angle Sensor





- Non-contact magnetic angle sensor with +/- 45 deg. range
- Proportional analog output

The Vision of Fly-By-Wire for Experimental Aircraft

- Automated flight control for light aircraft today is limited to the capabilites of “traditional” general aviation autopilots which use existing or supplementary trim motors
- Affordable Inertial Navigation Systems (INS) have become available due to the success of electronic flight instruments (EFIS)
- Combining such an INS with new technology electric flight control actuators, advanced control concepts can be realized for light airplanes

Advanced Control Concept	**Target**
Automatic Turn Coordination	Stall/Spin Accident Prevention
Cruise Flight Side Slip Minimization	Performance Optimization, Fuel Saving
Automatic Configuration Change and Trim for Departure and Approach	Pilot’s Workload Reduction, Flight Envelope Protection
Autopilot Control Bandwidth Improvement	Pilot’s Workload Reduction
Gust Alleviation by Command and Stability Augmentation (CSAS)	Pilot’s Workload Reduction, Passenger Comfort

Integrated Servo System with CANaerospace Interface ("Smart Actuator")

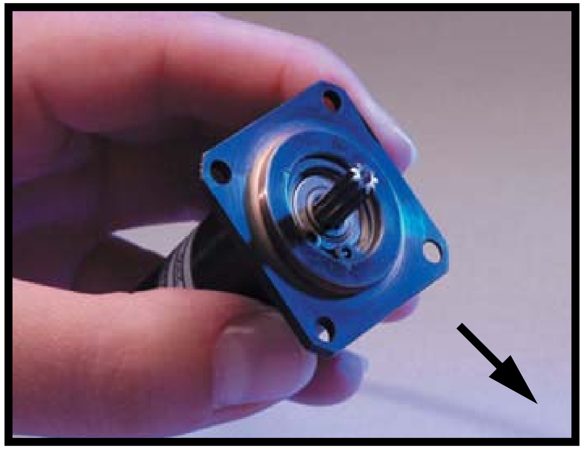
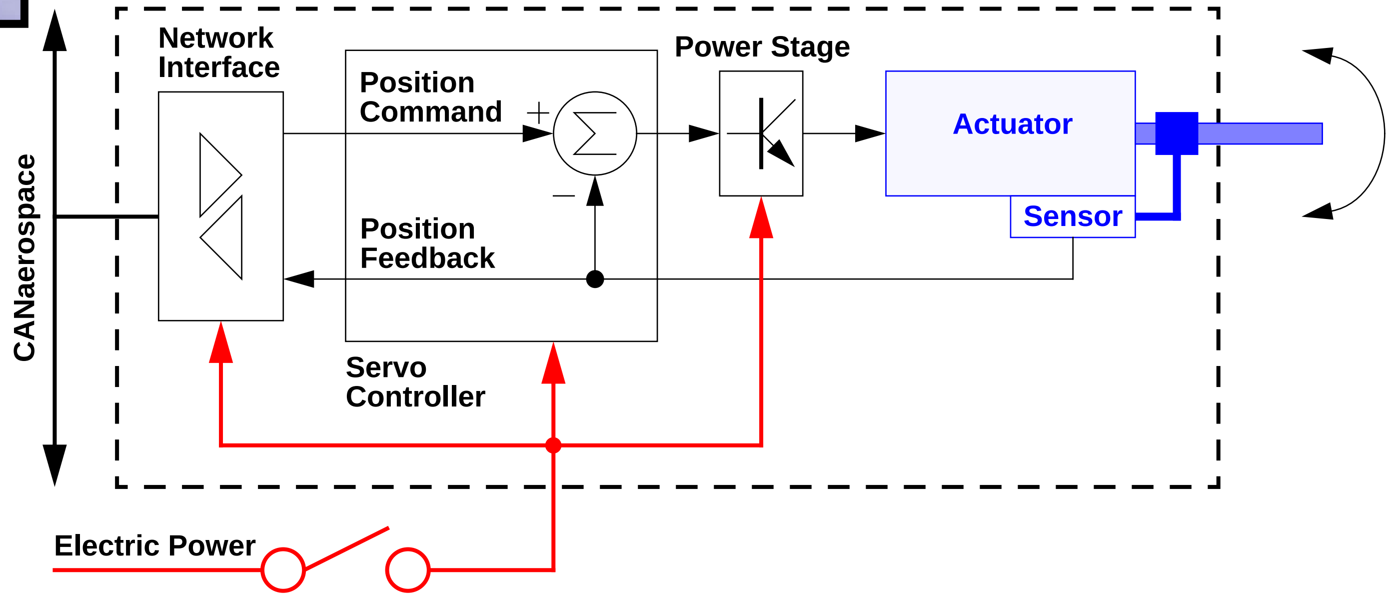
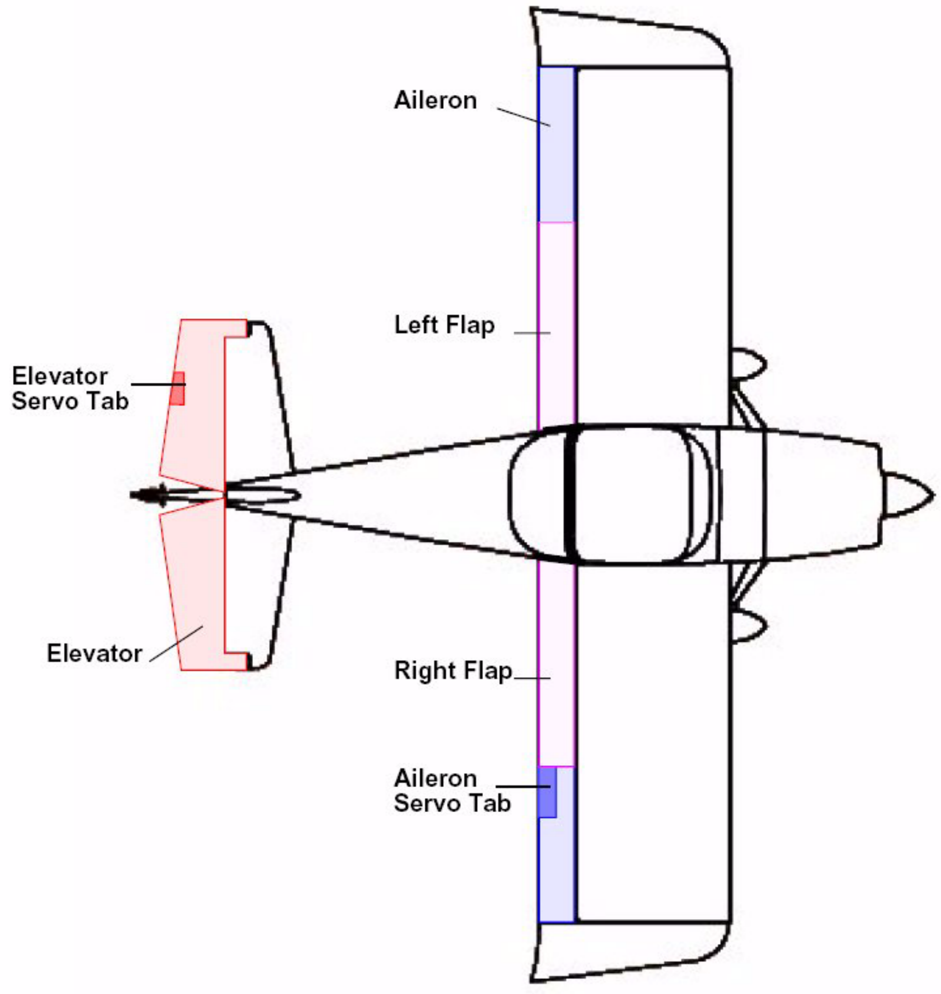


Photo:
Wittenstein Aerospace
(www.wittenstein.aero)

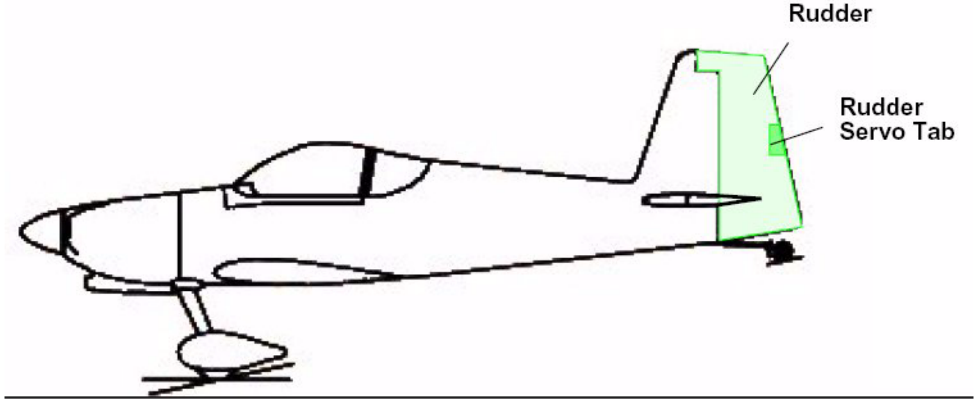
- Continuously receives target position commands and performs servo loop computation
- Continuously transmits actual position
- Performs built-in test and monitoring



Light Airplane with Control Surfaces supporting Advanced Flight Control Concepts

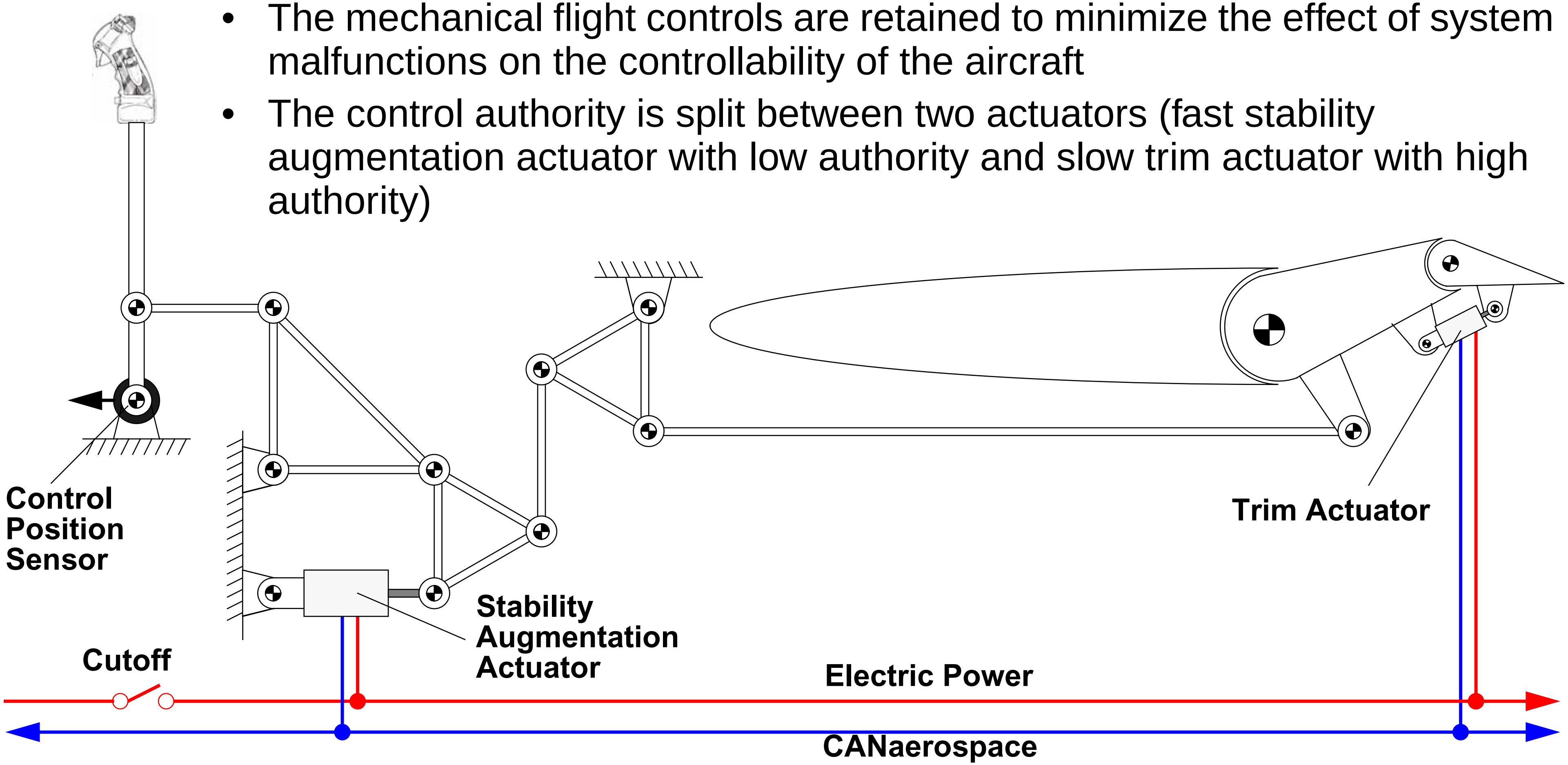


- Minimum configuration uses additional Flettner type servo tabs added to elevator, aileron and rudder
- Servo tabs, flaps and other secondary control surfaces controlled by smart actuators
- Speed brakes can be included if pilot override in case of malfunction is ensured

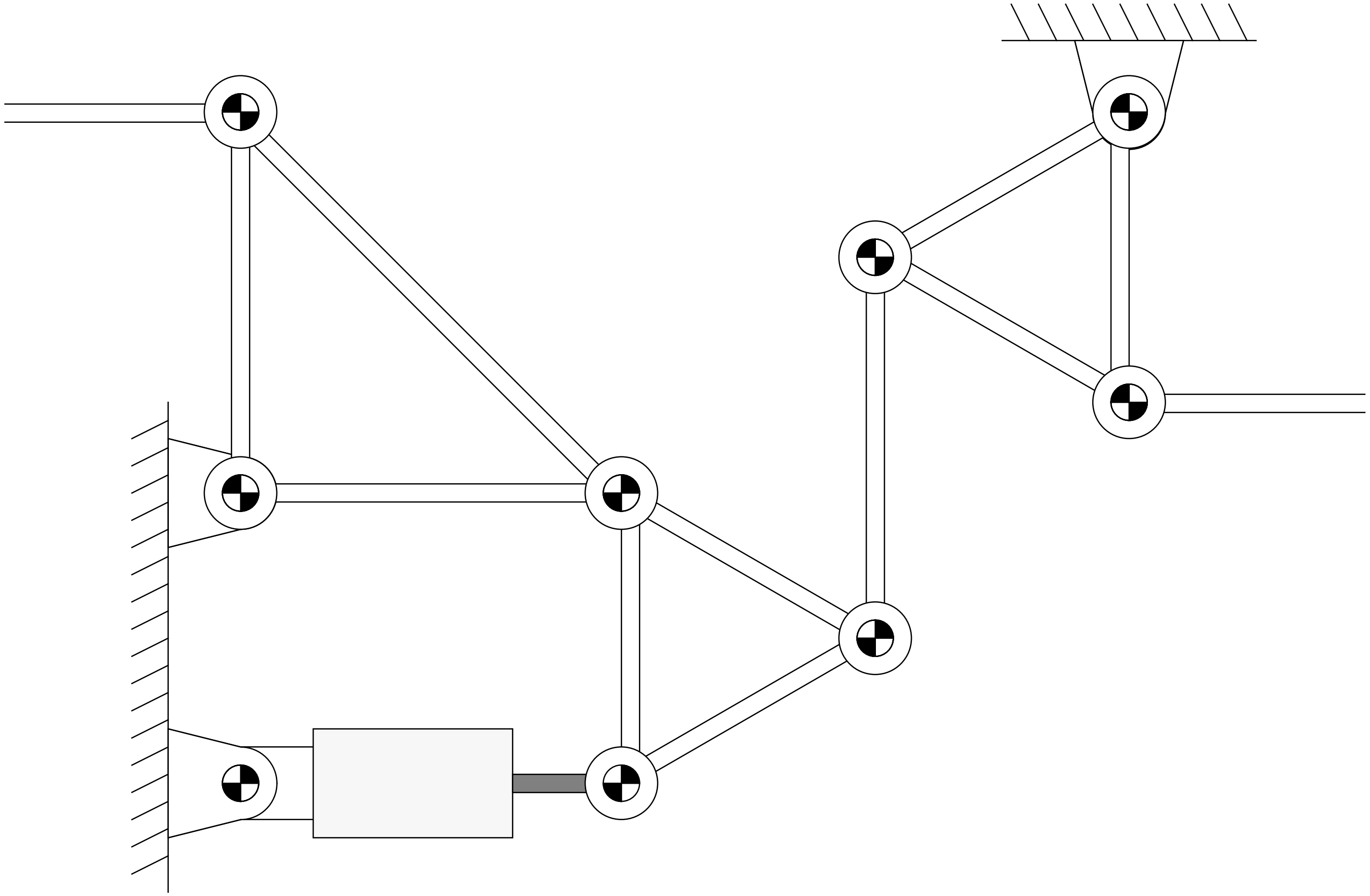


Integration of Mechanical Flight Control System with Smart Actuators

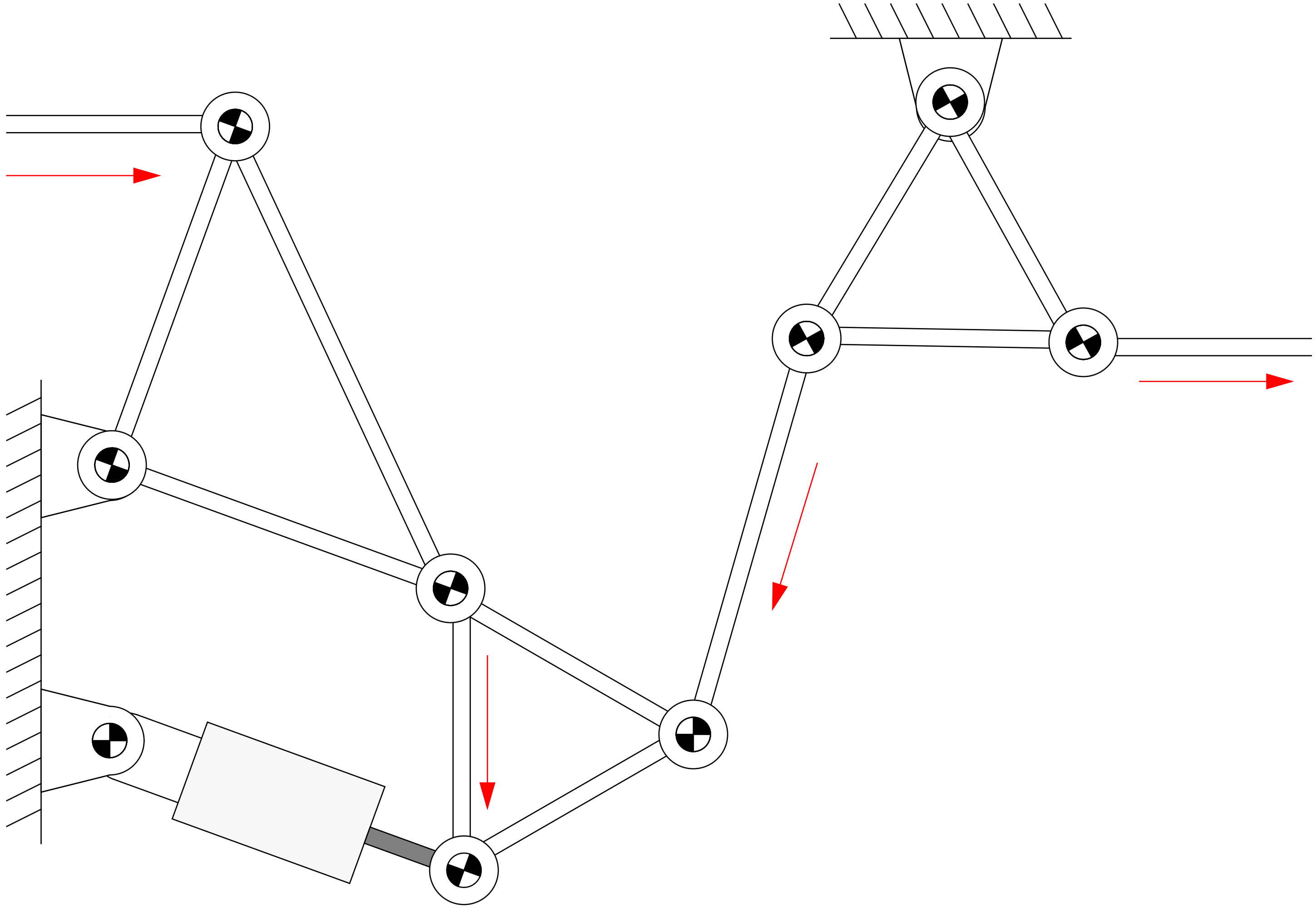
- The mechanical flight controls are retained to minimize the effect of system malfunctions on the controllability of the aircraft
- The control authority is split between two actuators (fast stability augmentation actuator with low authority and slow trim actuator with high authority)



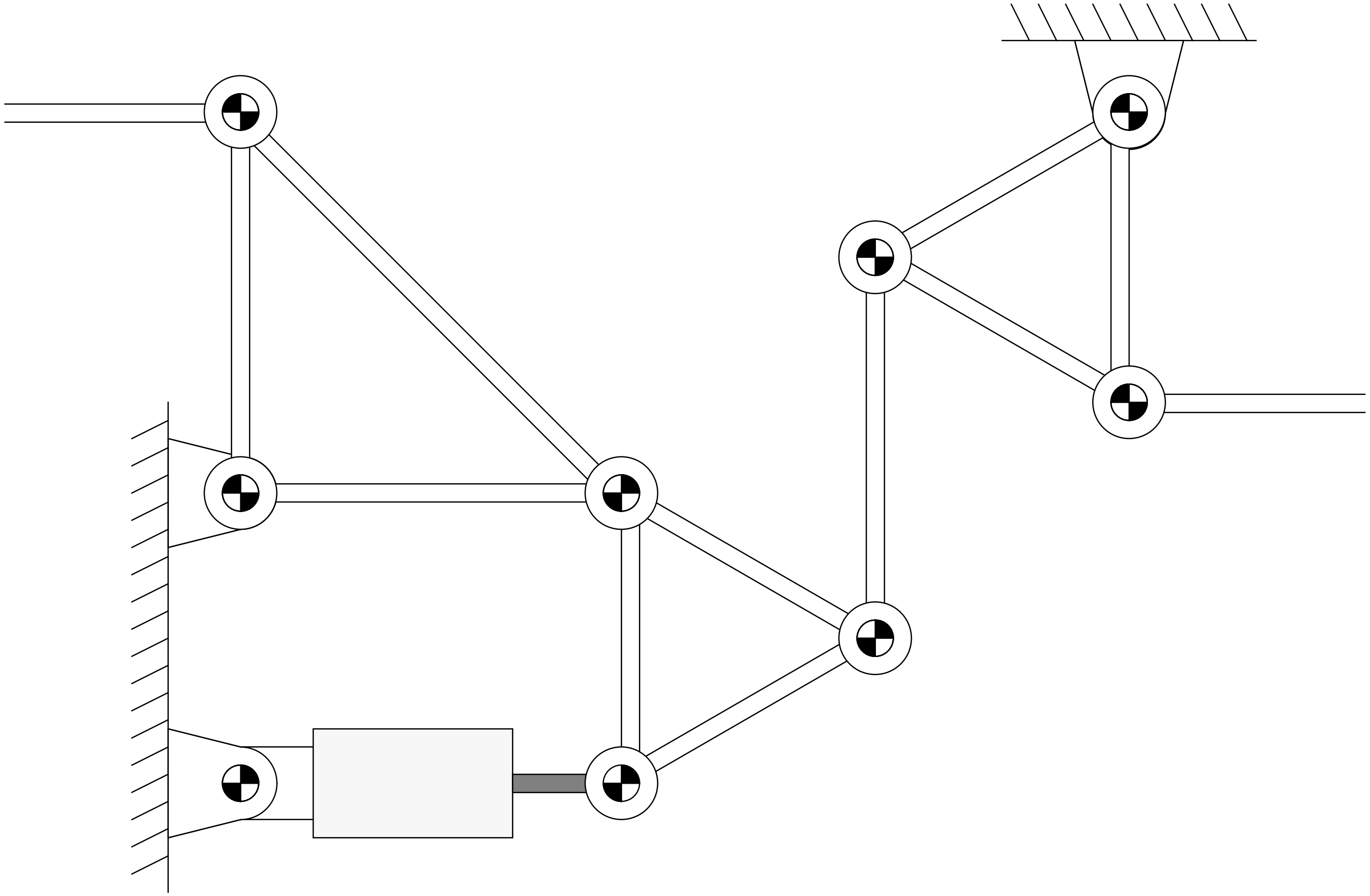
Adding Flight Control Link Kinematics



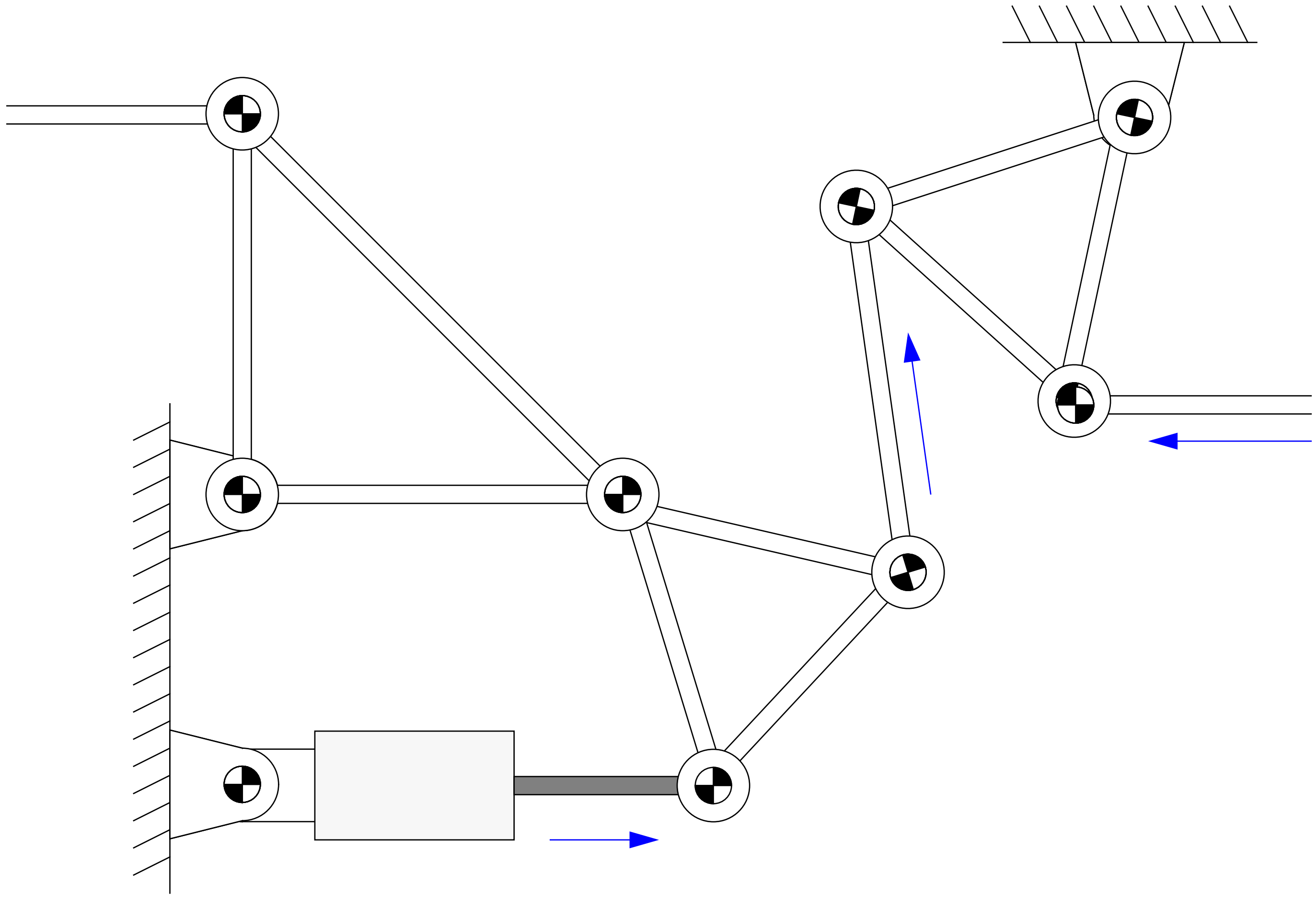
Adding Flight Control Link Kinematics Pilot Control Input



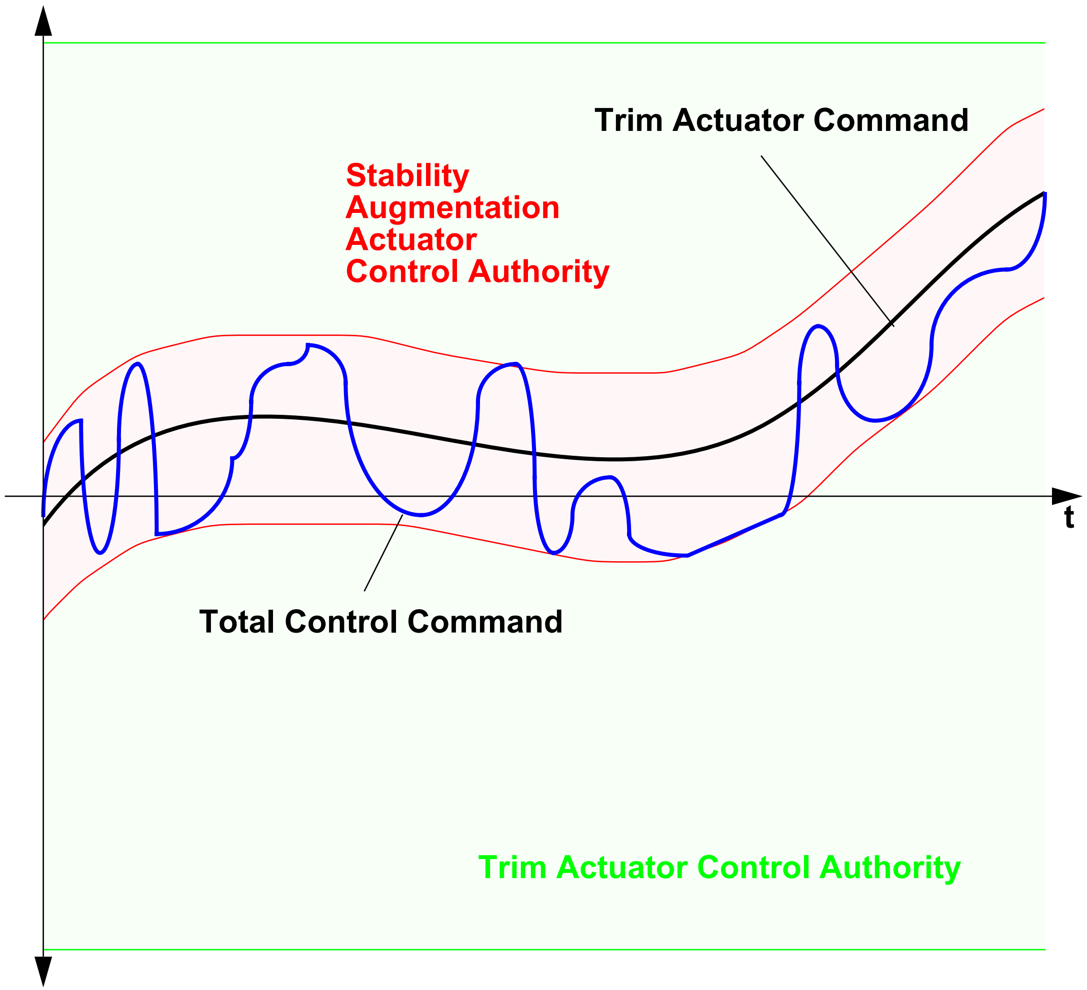
Adding Flight Control Link Kinematics



Adding Flight Control Link Kinematics Stability Augmentation Actuator Control Input

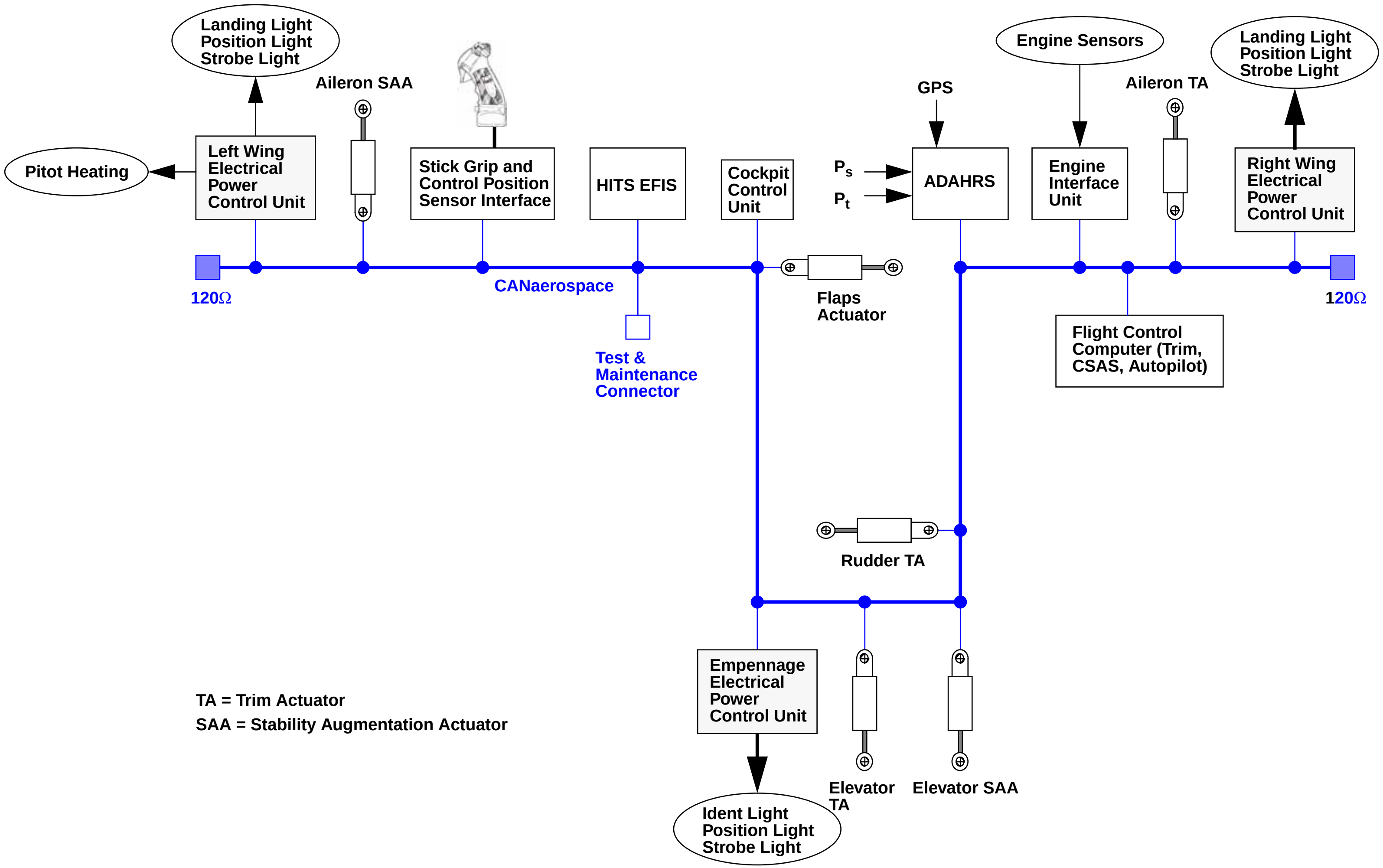


Actuator Control Allocation



- Control allocation directs high frequency positioning commands to the stability augmentation actuator and low frequency commands to the trim actuator
- The trim actuator continuously tries to prevent the stability augmentation actuator from reaching its position limits
- Stability augmentation actuator hard overs can be handled due to limited control authority
- Trim actuator hard overs can be handled due to low runspeed

CANaerospace-based Fly-By-Wire IMA Architecture



Conclusions and Outlook

- Integrated Modular Avionics (IMA) systems based on reliable avionics networks represent the heart of all new commercial airliners today
- The fast evolving computer and network technology has opened the door to IMA for light aircraft in an affordable way
- CANaerospace provides an IMA network that fulfils all requirements for mission and safety critical applications in aviation
- The RV-7ca project demonstrates that a CANaerospace-based IMA system can successfully be implemented for a light airplane at reasonable cost and effort
- The benefits of the RV-7ca project technology for homebuilders are obvious and verifiable
- Taking advantage of new developments in electric drive technology, a state-of-the-art advanced flight control system for light aircraft based on IMA and CANaerospace is feasible
- An alliance between kitplane manufacturers, homebuilders and avionics suppliers would have the potential to initiate the design of new or the upgrade of existing avionics components with CANaerospace interface, creating the basis for a substantial number of IMA systems in light aircraft