Instrumentation In 60 Minutes or Instro. Familiarization @ 25K Ft. ASL

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Training Objectives

- **Become familiar with:**
  - **Instrumentation Resources Available to the Test Engineer**
  - **Basic Definitions and logic**
  - **Instrumentation System Components**
    - Transducers
    - PCM & Airborne Instrumentation Systems
    - Signal Conditioning & Filtering
    - Time and Space
    - Data Recorders
    - RF Transmission (TM)
    - Data Reduction
    - Ground Support
- **Understand:**
  - **How Instrumentation can effect your Data**
  - **What you can do to help yourself including some lesson learned**

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Class ROE's

- One-Hour Sessions...10 Minute Breaks
  - Start at 7:30....End at 4:30 PM.
- Instructor's Available
  - During Lunch if you buy (only kidding), After Class
- Classroom Protocol
  - OK to Interrupt, OK to Stand Up, OK to Speak Up
  - Ask Questions at Any Time
- To get the most from this course
  - Share your experiences
    - YOU can be as much an instructor as we are
    - We don't have ALL the experience … YOU have a lot!

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Introduction of Class Participants

- ***Please stand up and tell everyone your:***
- **Name**
- **Organization**
  - Location
  - Type of product/service
- **Job Description**
  - Describe your job function
  - Number of years in your field
- **What Do You Hope to Learn From This Class?**
  - Special Application Problems

Instructor Introduction — Michael Golackson

michael.golackson@edwards.af.mil

- **EXPERIENCE**
- 1990 – Present Instrumentation Division, Edwards AFB, Chief of Instrumentation Operations, Supported various aircraft test programs including F15, F16, F22, F35, B2, B52, C17, and JSF CDP (X32/X35).
- 1990 Cycad, Systems Engineer on Project for Pt. Mugu BMO
- 1979 – 1989 USMC & USMCR Ground Radio Repairman, Experience includes support of OT types of activities including support of EW/CAS at Tonopah, Nv. and initial evaluation of different pieces of comm equipment.
- **EDUCATION**
- BSEE w/minor in Physics, attended RCC and CSUF 1984-1990 (Days and Evenings)
- **PROFESSIONAL AFFILIATIONS**
- Member, RCC Telemetry Group, R & R Committee
- Member, ITEA Lancaster Chapter
- Former member, IEEE Lasers and Fiber Optics Group

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Instructor Introduction — James Alich

james.alich@edwards.af.mil

- **EXPERIENCE**
- 1991 – Present Instrumentation Division, Edwards AFB, Chief of Modification Branch supporting various aircraft test programs including ARIA Test Support A/C, F15, C130 Combat Talon, Environmental testing on F117A
- 1989 – 1991 AFRL Rocket Site supporting Hover Test Facility and the LPX program
- **EDUCATION**
- BSEE University of Minnesota 1988
- **PROFESSIONAL AFFILIATIONS**
- Licensed P.E State of California 1996
- Member, American Watchmakers Institute
- Member, ITEA Antelope Valley Chapter

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Resources to learn more about the Art and Science of Instrumentation

- *Tim Gatton's TTI Class on Instrumentation. Contact information for Mr. Gatton is* tim.gatton@gmail.com
- *Peter Stein and Pat Walters Class on Measurement Science. Contact information for Mr. Pat Walters is P.Walter@tcu.edu*
- *Range Commanders Council (RCC) standards (especially IRIG 106-06) https://wsmrc2vger.wsmr.army.mil/rcc/pubs/pubs.htm*
- *WikiPedia (I love this web site) www.wikipedia.org*
- *Endevco's Handbook of Dynamic Force, Pressure, and Acceleration Measurement www.endevco.com*
- *AGARDograph Series 160 (Flight Test Instrumentation) www.stinet.dtic.mil/rto/agardographs.html*

Why Do We Need Standards?

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Too many solutions to a universal need

Range Commanders Council

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The Range Commanders Council (RCC) was founded in August 1951 upon the recommendation of the Commander, Naval Air Missile Test Center, Point Mugu, California, to the Commanding General, White Sands Proving Ground, New Mexico, and the then Commander, Patrick Air Force Base, Florida. It began as the Range Commanders Conference and later became the RCC in 1963.

The RCC structure consists of the Range Commanders, Executive Committee (EC), *standing and ad hoc groups*, as may be established, and the Secretariat.

The RCC is dedicated to serving the technical and operational needs of U.S. test, training, and operational ranges.

The responsibilities and relationships of the RCC are to proactively share insights and products with various services and DOD organizations.

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RCC Goals/Functions

- The RCC provides a framework wherein:
  - **Common needs are identified, and common solutions are sought**
  - **Technical standards are established and disseminated**
  - **Joint procurement opportunities are explored**
  - **Technical and equipment exchanges are facilitated**
  - **Advanced concepts and technical innovations are assessed, and potential applications are identified**
- The Range Commanders Council was organized to preserve and enhance the efficiency and effectiveness of member ranges, thereby increasing their research and development, operational test and evaluation, and training and readiness capabilities. The scope of the Range Commanders Council is to:
  - **Resolve common problems**
  - **Discuss common range matters in an organized forum**
  - **Exchange information thereby minimizing duplication**
  - **Conduct joint investigations pertaining to research, design, development, procurement, and testing**
  - **Coordinate major or special procurement actions**
  - **Develop operational test procedures and standards for present and future range use**
  - **Encourage the interchange of excess technical systems and equipment**

What is “IRIG”

- *Inter-Range Instrumentation Group (IRIG):* **The IRIG was formed by the Conference to do the work (standards …). Today only a few RCC standards documents retain the IRIG designation, while the others changed to the RCC designation .**
- *Telemetry Group:* **The RCC Telemetry Group (TG) formed in 1953 as part of the IRIG. The TG has four active committees (Data Multiplex, Recorder Reproducer, RF Systems and Vehicular Instrumentation and Transducer). The TG supports several documents IRIG 106, RCC 118,119,120 and 121. IRIG 106-xx Parts 1 and 2 (the telemetry (TM)standards) is the only document that retains the IRIG designation. The RCC TG maintains the TM system standards that are used by member ranges of the RCC. They contain many of the standards used in the flight test telemetry industry.**

IRIG-106 Telemetry Standards Part 1

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Chapter 1: Introduction

Chapter 2: Transmitter and Receiver Systems

Chapter 3: Frequency Modulation

Chapter 4: Pulse Code Modulation

Chapter 5: Digital Audio Telemetry

Chapter 6: Tape Recorder Standards

Chapter 7: Magnetic Tape Standards moved to appendices

Chapter 8: Digital Data Bus Acquisition Formatting Std.

Chapter 9: Telemetry Attributes Transfer Std. (TMATS)

Chapter 10: Digital Recorder Standard

IRIG-106 Telemetry Standards Part 1, cont.

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Appendix

- A Frequency considerations
- B Use Criteria for Frequency Division Multiplexing
- C Pulse Code Modulation
- D Magnetic Tape Recorder Use Criteria
  this appendix just picked up lots of old Chapter 6 and Chapter 7 items
- E Transducer Documentation
- F Continuously Variable Slope Delta Modulation
- H, I and J Telemetry Attributes Transfer
- K Pulse Amplitude Modulation
- List of Tables

IRIG-106 Telemetry Standards, cont.

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- **Part 1 is the traditional telemetry as outlined previously**
- **Part 2 discusses new telemetry networks.**
- **Many blanks still exist in Part 2 since this is work-in-progress (a “living” document) that is being updated as technology is being developed.**
- **IRIG standards are available on-line at http://www.jcte.jcs.mil/rcc/PUBS/pubs.htm**
- **See also: http://www.telemetry.org**

What's happening to IRIG Documents Today

- RCC Groups are meeting semi-annually
- Updates to some RCC Standards including:
  – Instrumentation Engineers Handbook
  – IRIG 106 Chapter 6, 9 and 10 being updated
  – RCC 118 Volume 3 Recorder Setup being updated to support Chapter 10
  – Part 2 is being developed under support by DOD CTEIP Office

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Basic Definitions

- **Instrumentation is defined as the art and science of *measurement* and *control*".**
- **Instruments are devices which are used in measuring our physical world. The variable/measured can include practically any measurable event related to the physical sciences. These physical events include:**
  - **Pressure**
  - **Flow**
  - **Temperature**
  - **Level**
  - **Current**
  - **Voltage**
  - **Frequency**
  - **Chemical properties**
  - **Etc….**
- **Instruments can often be viewed in terms of a simple input-output device. For example, if we "input" some temperature into a thermocouple, it "outputs" some sort of signal. (Which can later be translated into data.) In the case of this thermocouple, it will "output" a signal in millivolts.**

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Basic Definitions, cont.

- Instrumentation Engineering is the engineering specialization focused on the design, configuration and maintenance of automated systems.
- Instrumentation Engineers usually (but not always) have degrees in Instrumentation Engineering, Electrical Engineering, Mechanical Engineering, Chemical Engineering, Physics, and sometimes even in Aerospace Engineering. Ok any engineer who likes to work with manufacturing and maintenance personnel could become an Instrumentation Engineers.
  - Typically work for industries with automated processes, such as chemical or manufacturing plants, with the goal of improving system productivity, reliability, safety, optimization and stability.
  - Integral Partner with the other test engineers and analyst on any test and evaluation test project
- Instrumentation Technicians specialize in the installation, troubleshooting and repairing instruments and instrumentation systems. This trade is so intertwined with electricians, pipe-fitters, power engineers, and engineering companies, that they could find him/herself in extremely diverse working situations.

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Basic Definitions, cont.

- Digitizing or digitization is representing an object, an image, or a signal (usually an analog signal) by a discrete set of its points or samples.
- Analog-to-Digital converter (abbreviated ADC, A/D or A to D) is an electronic circuit that converts continuous signals to discrete digital numbers. The reverse operation is performed by a digital-to-analog converter (DAC).
  - Typically, an ADC is an electronic device that converts an input analog voltage to a digital number. The digital output may be using different coding schemes, such as binary and two's complement binary.
  - Resolution can also be defined electrically, and expressed in volts. The voltage resolution of an ADC is equal to its overall voltage measurement range divided by the number of discrete values. One example:
  - Example 1
    - Full scale measurement range = -10.24 to 10.24 volts
    - ADC resolution is 12 bits: 2^{12} = 4096 quantization levels
    - ADC voltage resolution is: (10.24V-(-10.24V)/4096 count = 0.005 V/count = 5 mV/count

Basic Definitions, cont.

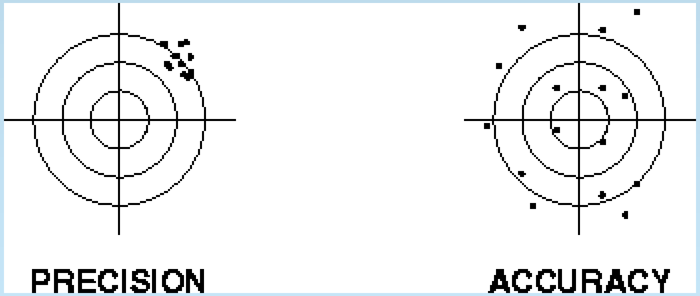
- Measurement is the estimation of a physical quantity such as length, temperature, or time.
  - Measurements are the ratio of some physical quantity to a standard quantity of the same type, thus a measurement of length is the ratio of a physical length to some standard length, such as a standard meter.
  - Measurements are usually given in terms of a real number times a unit of measurement, for example 2.53 meters.
  - Measurements always involve some error, and so in science measurements are often accompanied by error bounds, as in 2.53 meters plus or minus .01 meters. The study of measurement is called metrology.

- Uncertainty of a measurement is found by repeating the measurement enough times to get a good estimate of the standard deviation of the values. Then, any single value has an uncertainty equal to the standard deviation. However, if the values are averaged and the mean is reported, then the averaged measurement has uncertainty equal to the standard error which is the standard deviation divided by the square root of the number of measurements.

Basic Definitions, cont.

Accuracy versus Precision - What is the Difference?

An accurate measurement is one that is very close to the true value of the event you are monitoring. A precise measurement is one that has very little scatter: repeat measurements give more or less the same value. If the measured data has high precision but poor accuracy, one may suspect that a systematic bias has been introduced: you are using an instrument where the zero position has not been set properly.



Precision is a measure of repeatability while accuracy refers to how close the average value is to the "true" value.

If you do not know the expected value of a phenomenon but are trying to determine just that, it is obviously better to have accurate observations with poor precision than very precise, but inaccurate values. Why? The former will give a correct, but imprecise estimate while the latter will give a wrong, but very precise result!

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Why do we instrument our World?

History

- Units of measurement was among the earliest tools invented by humans. Primitive societies needed rudimentary measures for many tasks: constructing dwellings of an appropriate size and shape, fashioning clothing, or bartering food or raw materials.

- The earliest known systems of weights and measures seem to have all been created sometime in the 4th and 3rd millennia BC among the ancient peoples of Mesopotamia and Egypt. The most astounding of these ancient systems was perhaps that of the Indus Valley Civilization (Iran) (ca. 2600 BC). The Indus Valley peoples achieved great accuracy in measuring length, mass, and time. Their measurements were extremely precise (a unit was 1.704mm).

Why do we instrument our World?

Why we are instrumenting our world today:

- We design, develop and manufacture instrumentation systems for several reasons
  - Process and industrial monitoring
  - Control and factory automation
  - Real time information systems
  - Test and measurement (including calibration)
- Flight Test Instrumentation (FTI) is used to support the test and evaluation of air vehicles and therefore at times all parts of the instrumentation discipline are required.

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Why do we instrument our World?

- **Do you need flight test instrumentation equipment installed on your air vehicle?**
  - **You should consider the risks and operational environment!**
  - **If you are interested in what an aircraft is doing, but it departs from flight or simply crashes, is it the "end of the world"? Can the data be recorded "on-board" and be "recovered from the scene"?**
  - **What is the complexity of the aircraft and data? Boeing 777 has tens of thousands of parameters …. Can a pilot monitor that much information and accurately report back?**
  - **What is the risk to the platform? If a missile explodes, can you figure out what happened without the data?**
  - **If an aircraft is flying, does the data need to be monitored on the ground?**

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Delta 2

Fleet Ballistic Missile

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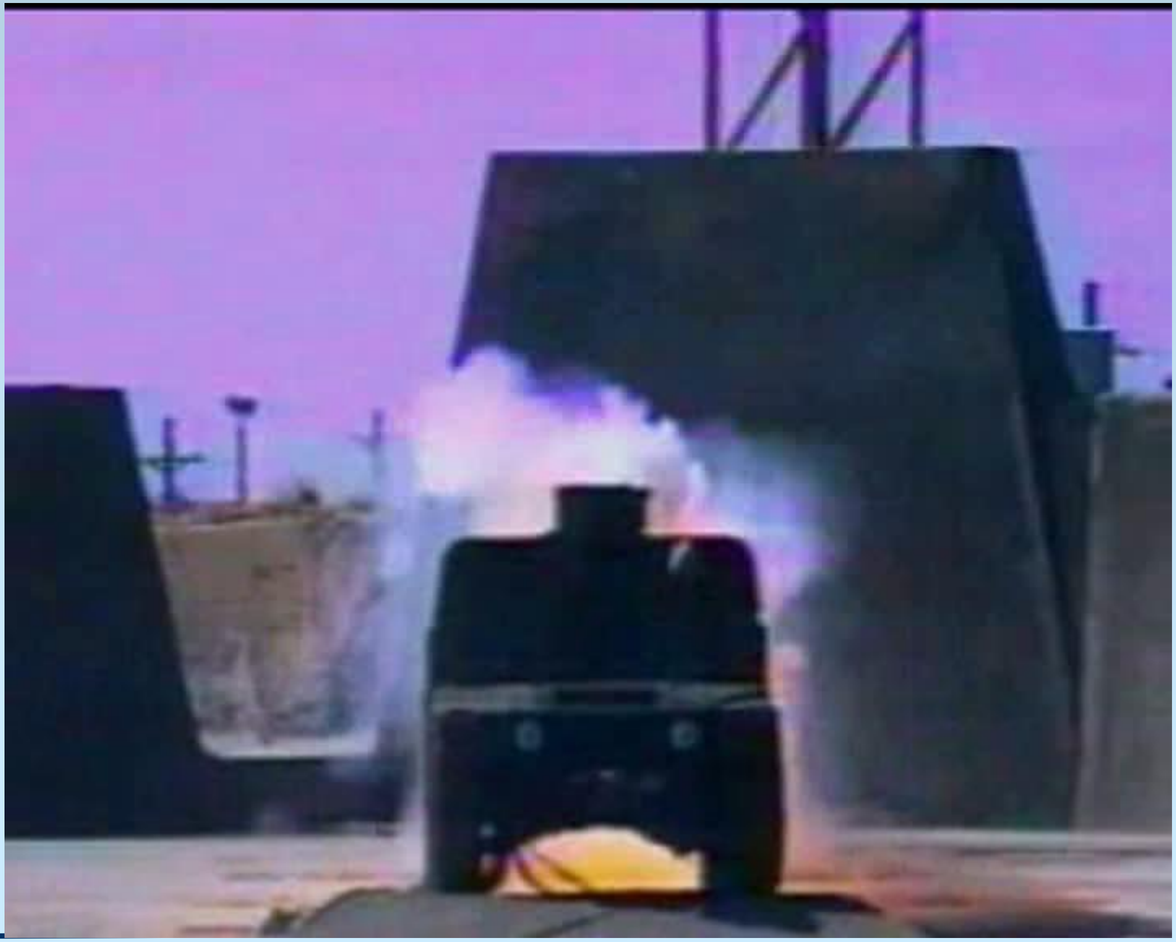
Commercial Aviation

And even when things go right …

- Do you think knowing the stresses on the launcher is important, what corrections occurred in flight on the missile, and what was the overall result of the test?



- If everything is destroyed, we are simply guessing at what happened?.

This does not cut it!

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Instrumenting an Aircraft

- **OBSERVATION: Most test programs under estimate the cost and schedule required to properly plan, design, document, install and checkout the instrumentation needed by a flight test program.**
- **Remember the 5 p's of being a boy scout (proper planning prevents poor performance)**
- **The four simple steps required to instrument any aircraft are:**

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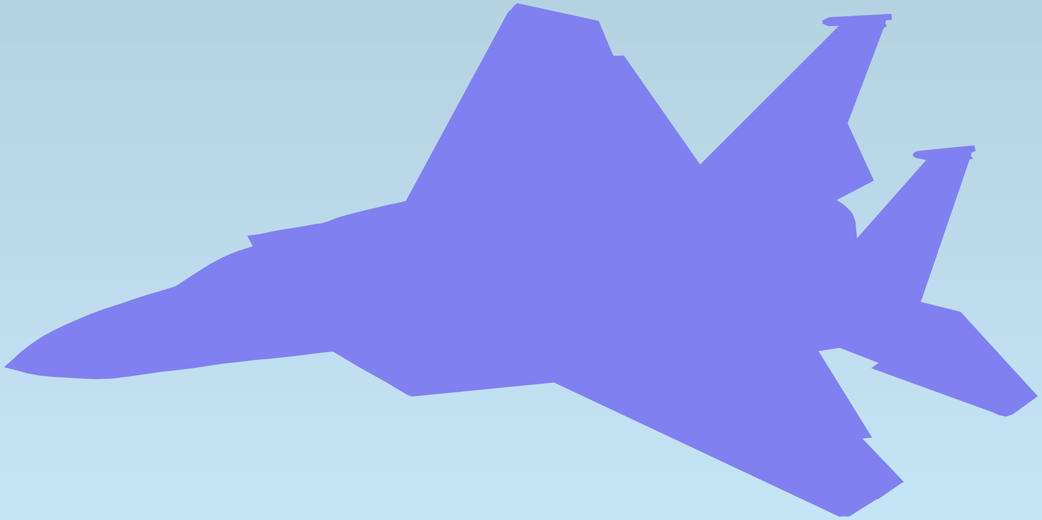
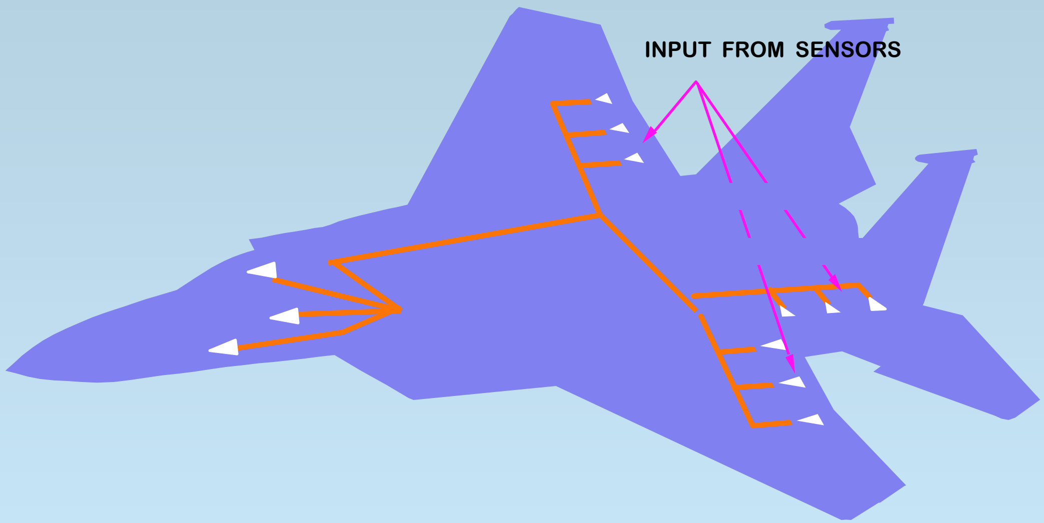
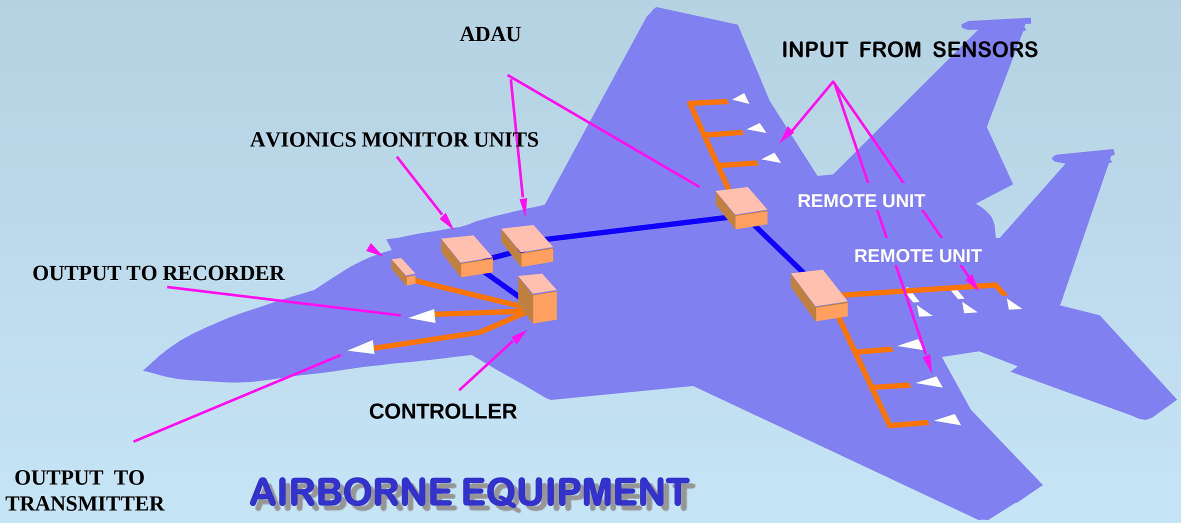
Step 1. Get an aircraft that can fly



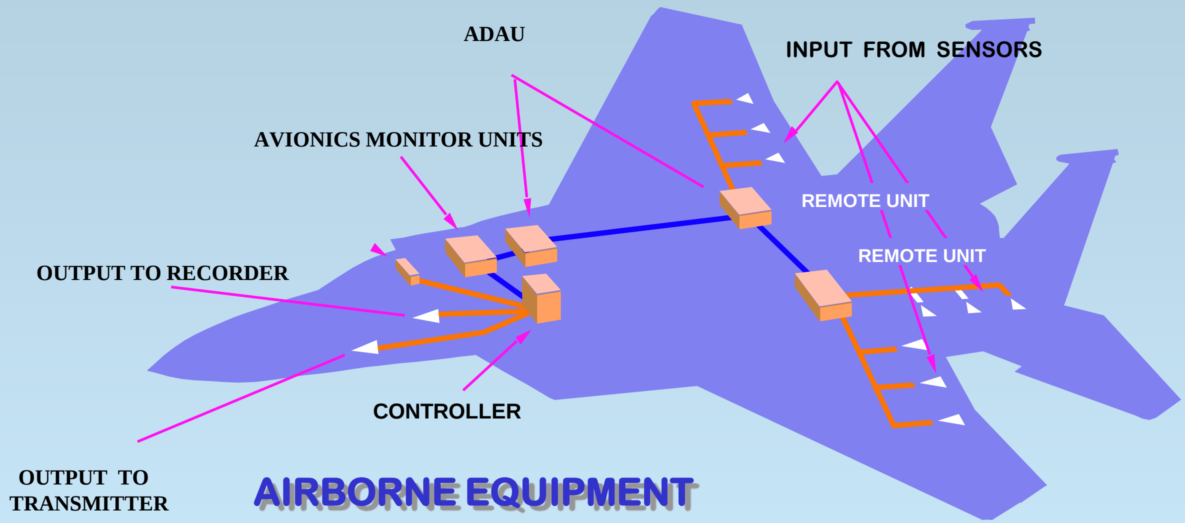
Step 2. Install up to 200,000 feet of orange wires, and a whole lot of transducers.

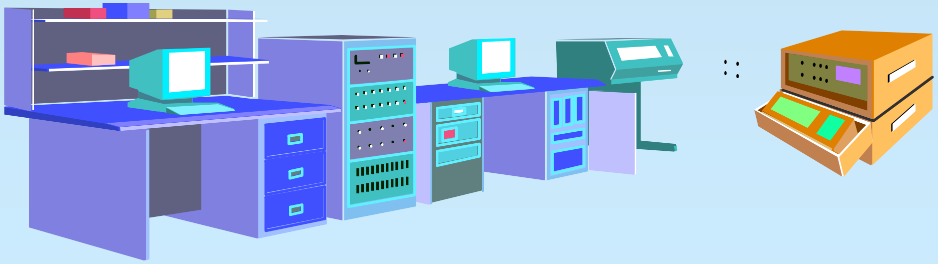


Step 3. Connect all the wires to a bunch of Orange boxes in the aircraft.



Step 4: Obtain Ground Support Equipment to support and process the information recorded by the orange boxes.





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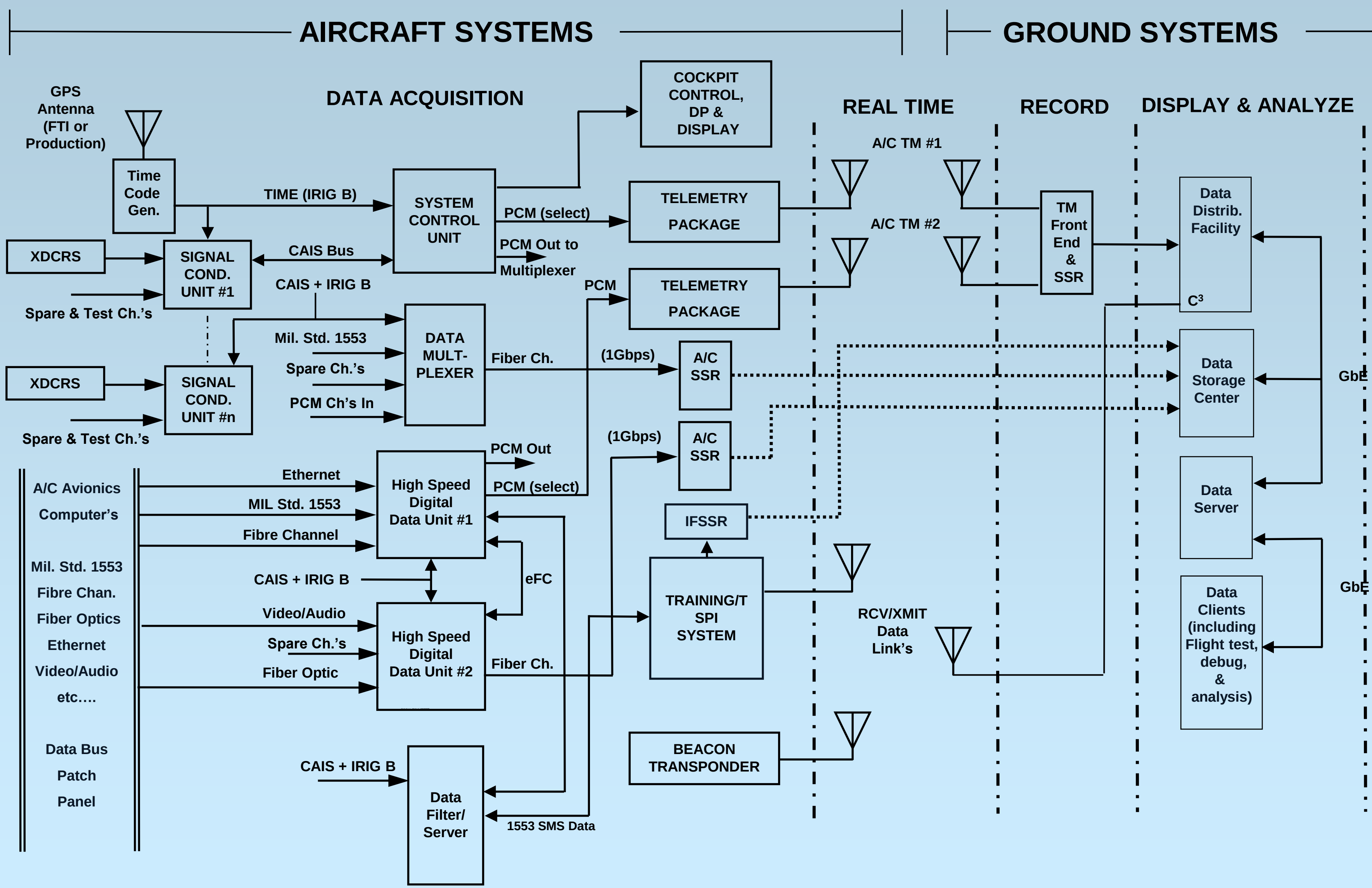
Instrumenting an Aircraft

- **Design of an instrumentation system requires a measurement list from the test engineers as early as possible which is based on the current test program requirements.**
- **The measurement list should contain at a minimum the following:**
  - Test Item: Measurement nomenclature (Parameter Name)
  - Range: nominal full scale value of the parameter of values expected
  - Accuracy: What is an acceptable uncertainty (%)
  - Resolution:
  - Frequency Response
  - Location on Aircraft
  - Environmental Conditions: Approximation is exceptal
  - Measurement Priority (Go/No Go requirement for different stages of test program)
  - Any additional Notes
- **The Instrumentation Engineer should work with the test engineer to validate the measurement list requirements in order to prevent excesses that cost the test program unnecessary cost and schedule.**
- **The Instrumentation engineer should based on the finalized measurement list organize the data requirements by frequency response and accuracy requirements. Once this occurs a basic instrumentation block diagram can be generated.**

Basic Instrumentation Data Acquisition System (DAS) Block Diagram



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Aircraft Data Acquisition System

- **The basic building blocks to any aircraft data acquisition system are:**
  - **Transducers**
  - **Signal Conditioning**
  - **Encoder/Controllers**
  - **Time & Position Reference Systems**
  - **Data Recorders**
  - **Telemetry Transmitters and Receivers**

Questions on Instrumentation??