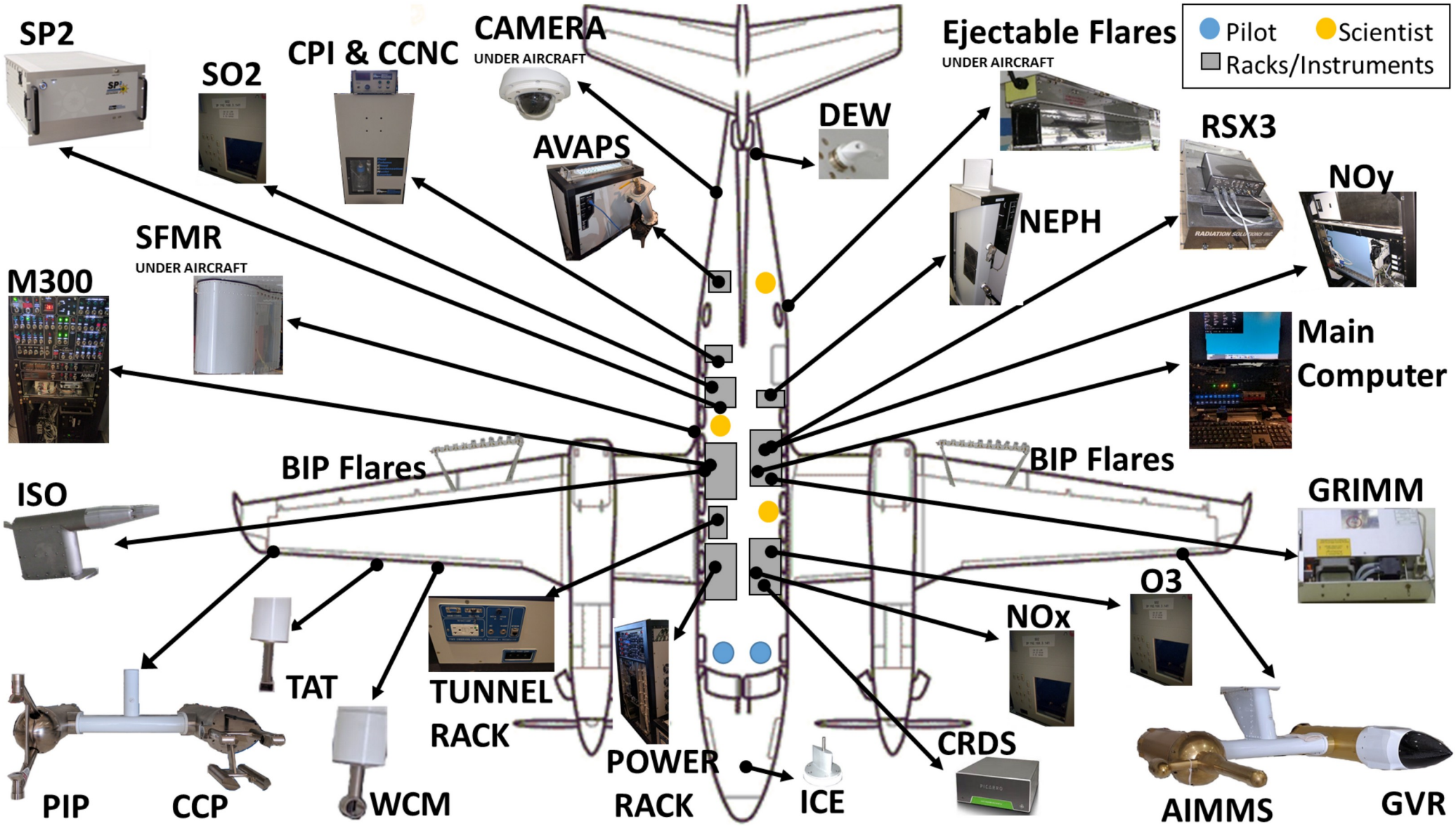
Airborne Analog and Digital Data

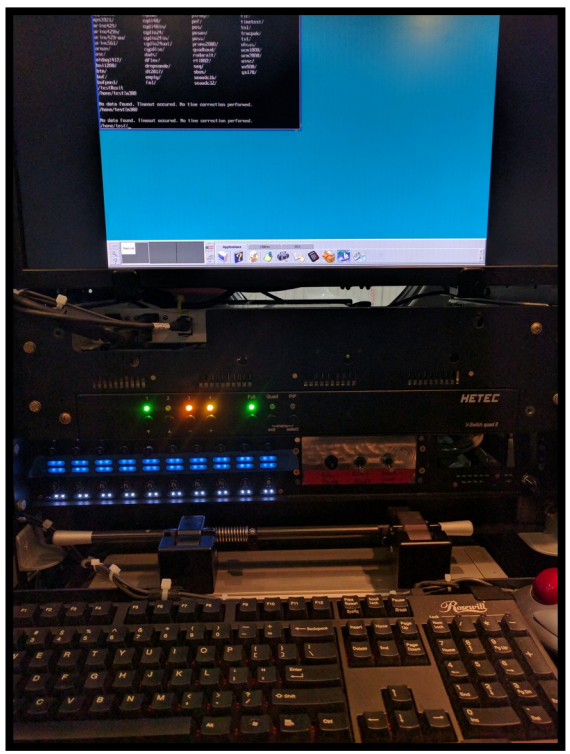


Dr. David Delene

University of North Dakota

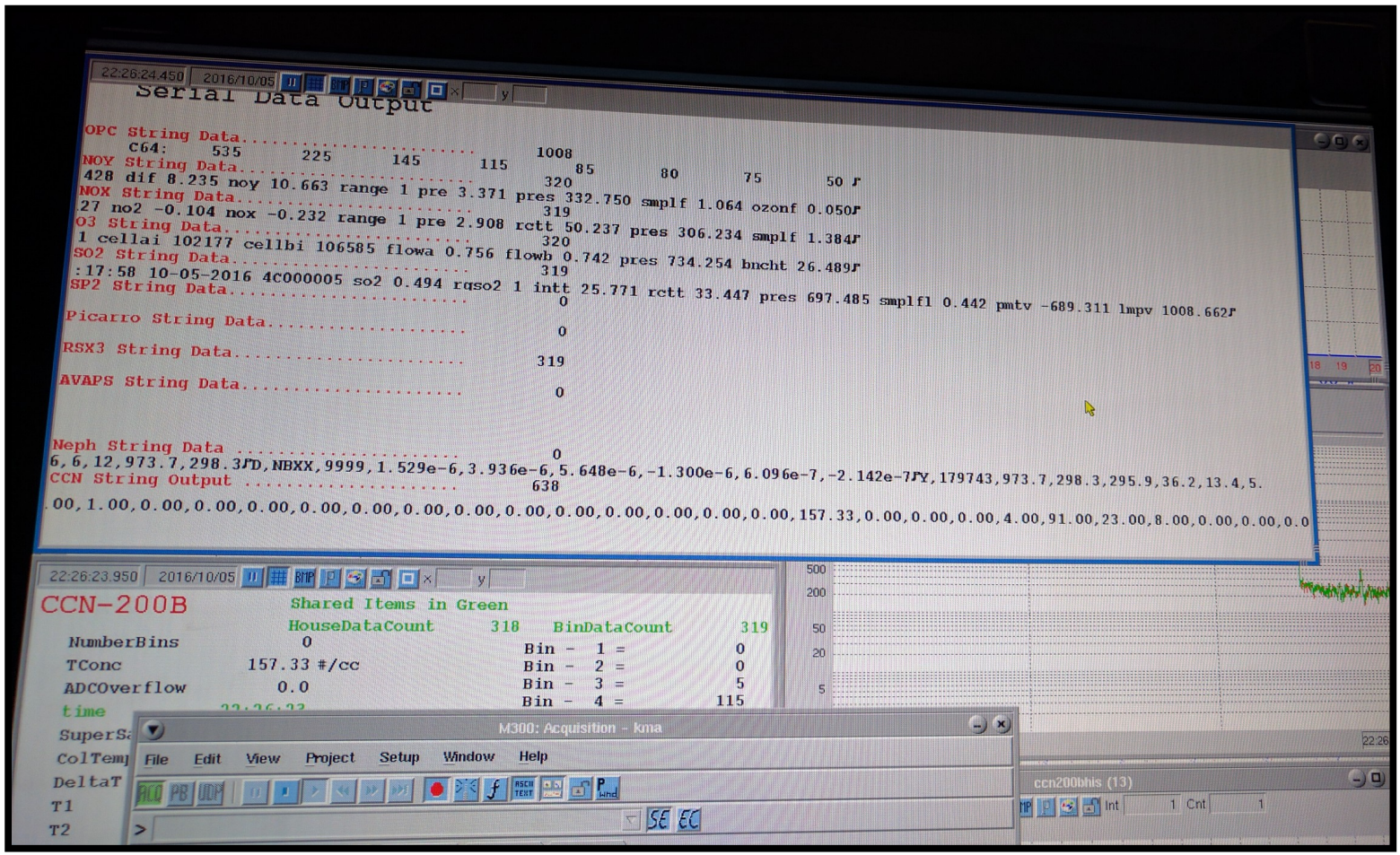
Science Engineering Associates Model M300 Data Acquisition System (M300)

- The M300 acquires all data on the KMA King Air 350 aircraft.
- Some instruments also acquire data.
  - AIMMS
  - CCNC
  - CRDS
  - SFMS
  - SP2



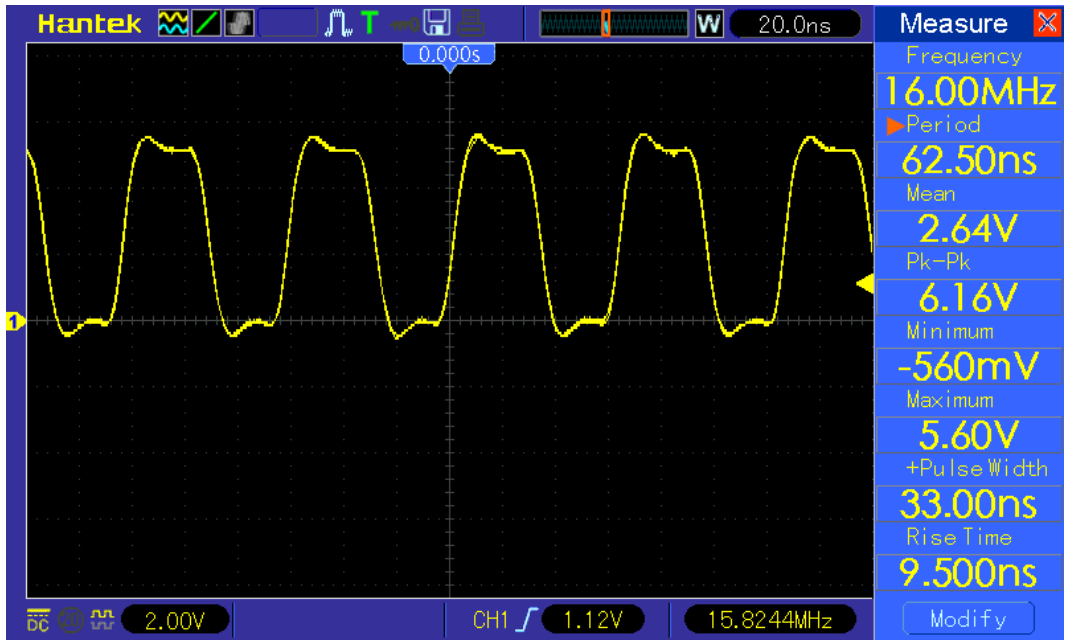
M300 Data Acquisition System

- Real-time Computer System (QNX OS)
- Optimized for Research Aircraft
- Totally Configurable Display System.



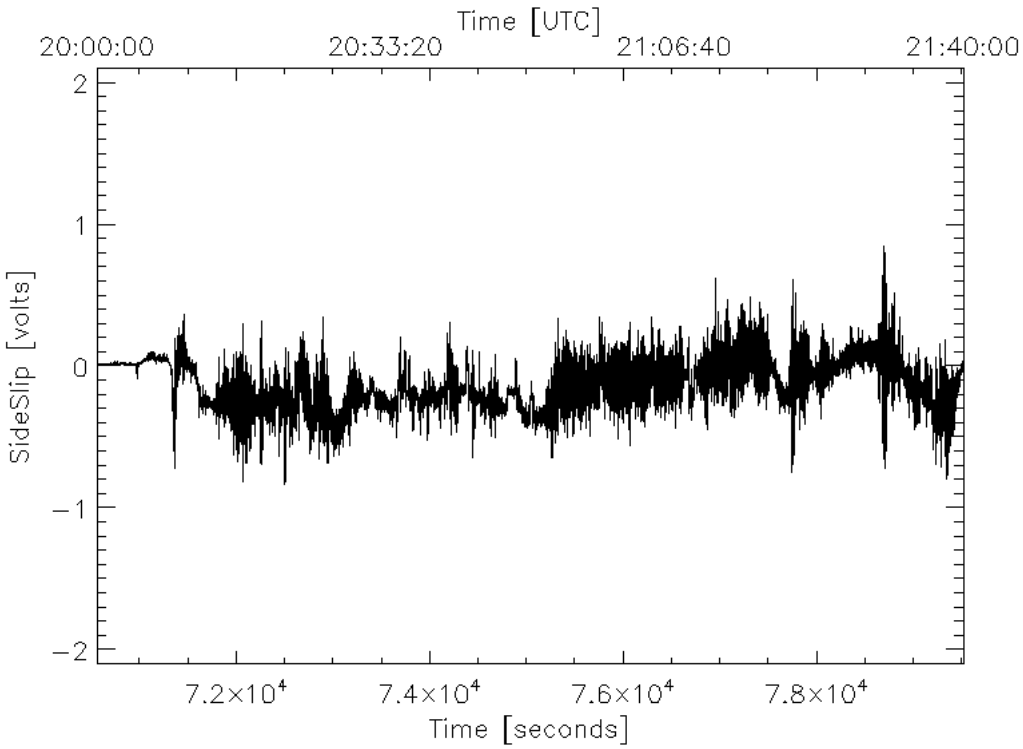
Types of Data Transmission

- **Analog**
  - Measure voltage (or current) over a range
    - 0-10 volts, +/- 10 volts, +/- 5 volts
- **Digital**
  - **Two Voltage Levels**
    - Represent 0 and 1.
  - **Error Checking**
    - Check Sums
  - **Ethernet**
    - Resend bad packages.

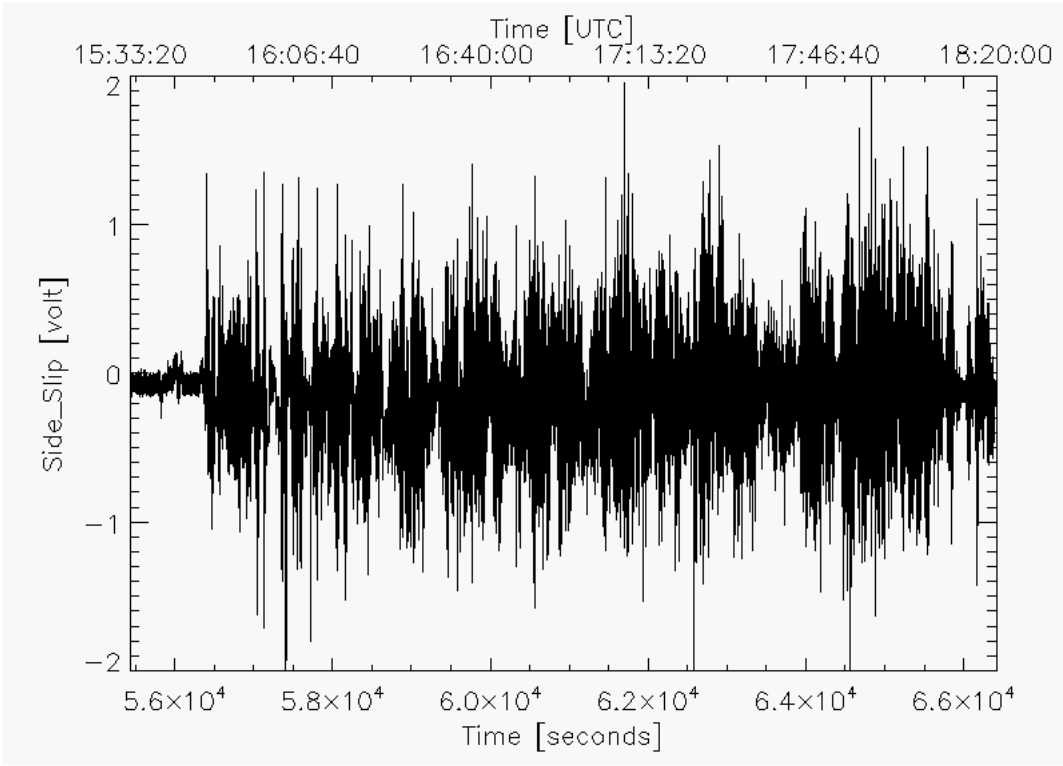


Analog Voltage Measurement

29 SEP 2005



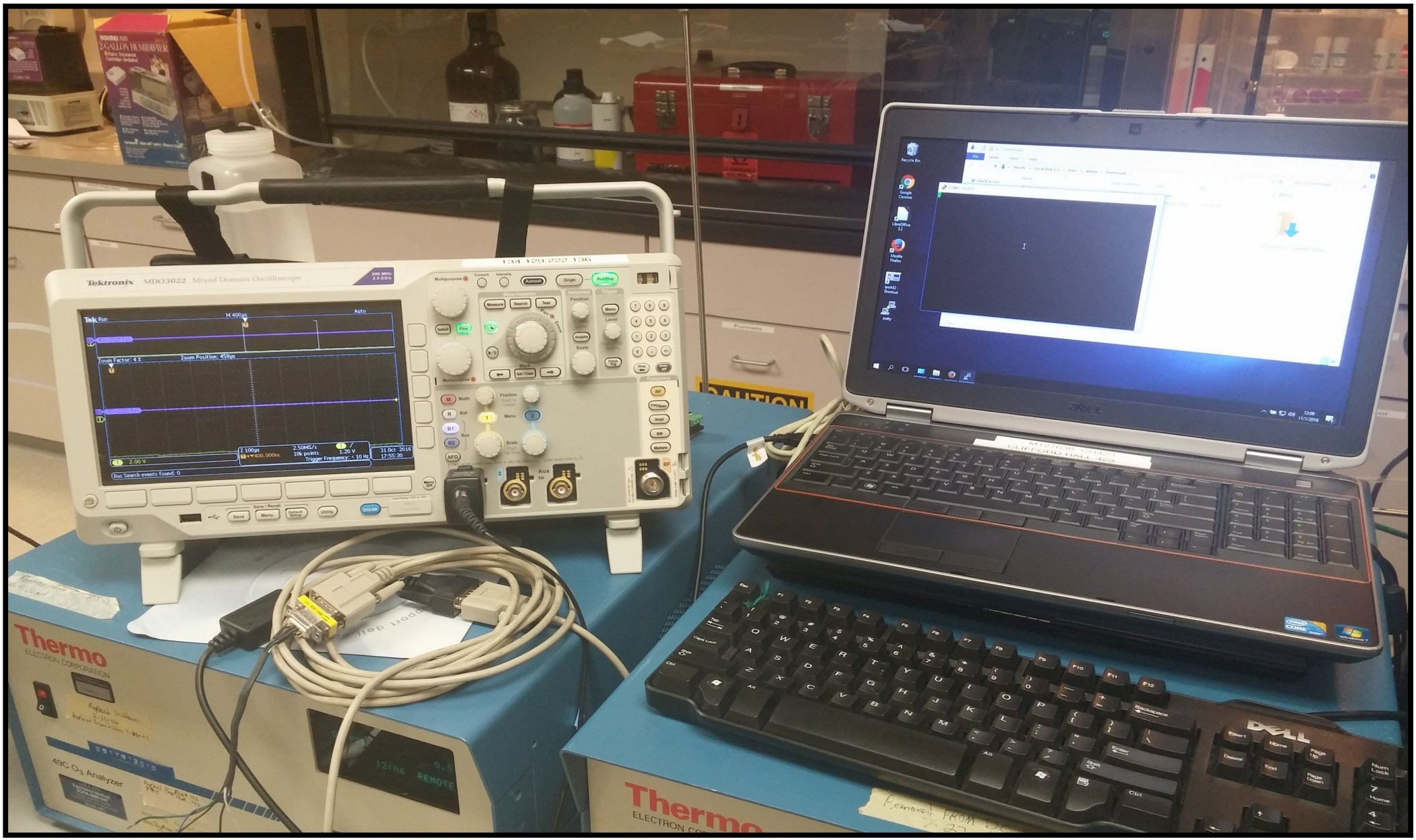
2 SEP 2012



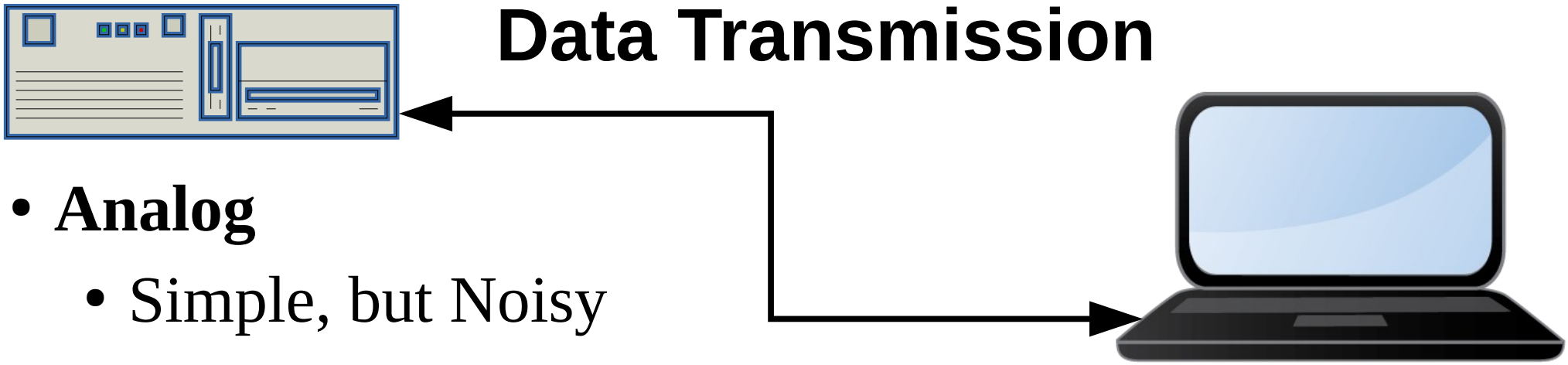
Voltage measurement from the side slip pressure transducer on the North Dakota Citation Research Aircraft.

Digital Data Acquisition

Serializes Data (RS-232)



Data Transmission



- **Analog**
  - Simple, but Noisy
    - 500,000 Samples per Second
- **Digital**
  - **UART (RS-232 / RS-422)**
    - Low Speed Communication (< 1 Mbit/sec)
    - Point-to-Point
  - **Ethernet (TCP/UDP) [Network/Fiber Cables)**
    - Higher Speed Communication
      - (100 Gbit/sec)
    - Interconnect Number of Boxes

Measurement Statistical Uncertainty

- To improve our certainty in a measurement, we can make repeated measurement.
- Repeated measurements can be represented as a Histogram that represents how the measurements are distributed.
- What single number best characterizes the complete group of measurements?
  - Mode – The value(s) the come up most often.
  - Median – The value where 50% of the measurements are above the value and 50% below.
  - Mean – Sum of all measurement divided by number of measurements.

Information Representation

Binary (Zeros and Ones)

- 01000101
- What is the Decimal Value?
- What is the Hex Value?
- What is the ASCII Text Character?

Esc	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12	Print	Scroll Lock	Pause
1B (1B) <1B> []	0,3B (0,54) <0,5E> [0,68]	0,3C (0,55) <0,5F> [0,69]	0,3D (0,56) <0,60> [0,6A]	0,3E (0,57) <0,61> [0,6B]	0,3F (0,58) <0,62> [0,6C]	0,40 (0,59) <0,63> [0,6D]	0,41 (0,5A) <0,64> [0,6E]	0,42 (0,5B) <0,65> [0,6F]	0,43 (0,5C) <0,66> [0,70]	0,44 (0,5D) <0,67> [0,71]	0,85 (0,) <0,> [0,]	0,86 (0,) <0,> [0,]	2A() <0,72> []		()

CODE (in	LEGEND Hexadecimal)
Extended Code- 0,XX	Normal- XX Shift- (XX) Control- <XX> Alt- [XX]

~ `	! 1	@ 2	# 3	$ 4	% 5	^ 6	& 7	* 8	(9	) 0	_ -	+ =	BackSpace
60(7E) <> []	31(21) <> [0,78]	32(40) <0,3> [0,79]	33(23) <> [0,7A]	34(24) <> [0,7B]	35(25) <> [0,7C]	36(5E) <1E> [0,7D]	37(26) <> [0,7E]	38(2A) <> [0,7F]	39(28) <> [0,80]	30(29) <> [0,81]	2D(5F) <1F> [0,82]	2B(2B) <> [0,83]	08(08) <7F> []

Tab	Q	W	E	R	T	Y	U	I	O	P	{ [	}]	
	71(51) <11> [0,10]	77(57) <17> [0,11]	65(45) <05> [0,12]	72(52) <12> [0,13]	74(54) <14> [0,14]	79(59) <19> [0,15]	75(55) <15> [0,16]	69(49) <09> [0,17]	6F(4F) <0F> [0,18]	70(50) <10> [0,19]	5B(7B) <1B> []	5D(7D) <1D> []	Enter

Caps Lock	A	S	D	F	G	H	J	K	L	: ;	" '	
	61(41) <01> [0,1E]	73(53) <13> [0,1F]	64(44) <04> [0,20]	66(46) <06> [0,21]	67(47) <07> [0,22]	68(48) <08> [0,23]	6A(4A) <0A> [0,24]	6B(4B) <0B> [0,25]	6C(4C) <0C> [0,26]	3B(3A) <> []	27(22) <> []	0D(0D) <0A> []

Shift	Z	X	C	V	B	N	M	< ,	> .	? /	Shift
	7A(5A) <1A> [0,2C]	78(58) <18> [0,2D]	63(43) <03> [0,2E]	76(56) <16> [0,2F]	62(42) <02> [0,30]	6E(4E) <0E> [0,31]	6D(4D) <0D> [0,32]	2C(3C) <> []	2E(3E) <> []	2F(3F) <> []	

Ctrl	Alt	Macro	Space	\ |	Alt	Ctrl
		() <> []	20(20) <20> [20]	5C(7C) <1C> []		

Insert	Home	Page Up
0,52 () <>	0,47 () <>	0,49 () <>
Delete	**End**	**Page Down**
0,53 () <>	0,4F () <>	0,51 () <>

↑
0,48 () <>

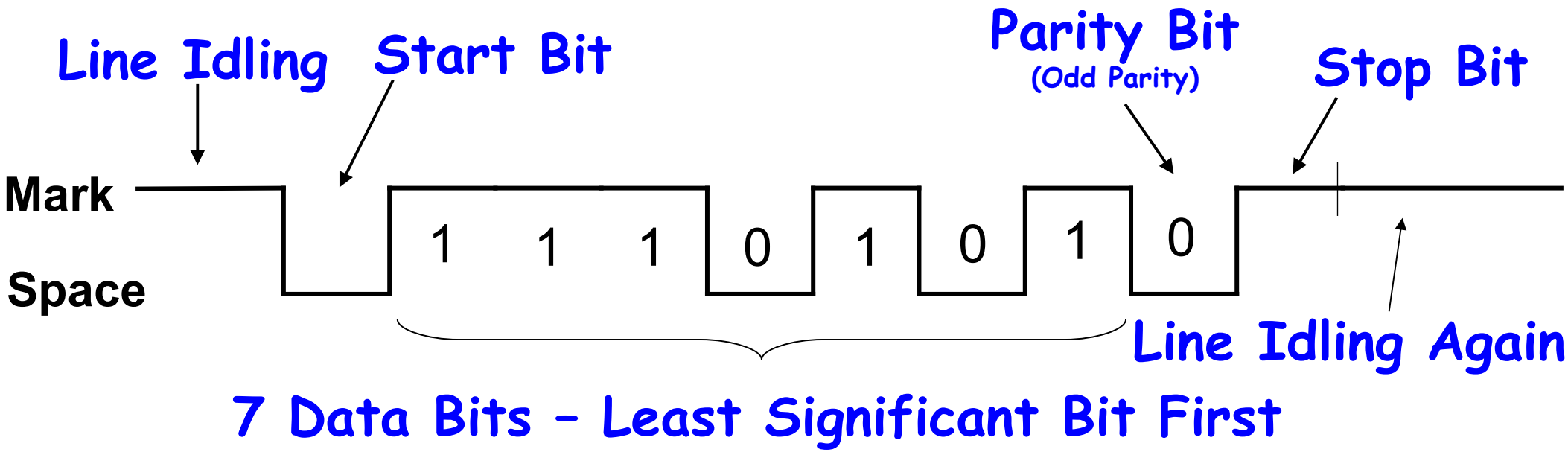
←	↓	→
0,4B () <>	0,50 () <>	0,4D () <>

Num Lock	/	*	-
7 Home	**8 ↑**	**9 Pg Up**	
0,47 (37) <0,77>	0,48 (38) <>	0,49 (39) <0,84>	+
4 ←	**5**	**6 →**	
0,4B (34) <0,73>	(35) <>	0,4D (36) <0,74>	
1 End	**2 ↓**	**3 Pg Dn**	
0,4F (31) <0,75>	0,50 (32) <>	0,51 (33) <0,76>	Enter
0 Insert		**. Del**	
0,52 (30) <>		0,53 (2E) <>	

Binary Data Transmission

- **Universal Asynchronous Receiver /Transmitter (UART) Example**

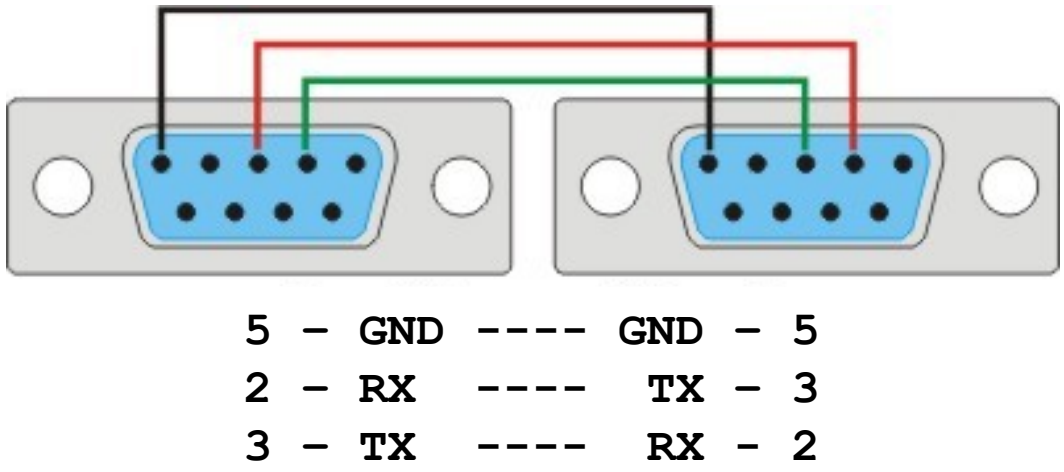
- **Send the ASCII letter ‘W’ (1010111)**



How would Least Significant Bit Last be different?

Adapted from BYU UART Lecture,
http://ece224web.groups.et.byu.net/lectures/UART.pdf

RS-232 Summary



- **Common Settings**
  - **9600 8-N-1**
  - **115,200 7-E-1**
- **Speed**
  - Serial ports use two-level (binary) signalling, so the data rate in bits per second is equal to the symbol rate in baud.
- **Data Bits**
  - The number of data bits in each character.
    - 7 for ASCII Data
- **Parity (N-None, O-Odd, E-Even, M-Mark, S-Space)**
  - Method of detecting errors in transmission.
- **Stop Bits**
  - Detect the end of a character.

Necessary of Post-processing Data

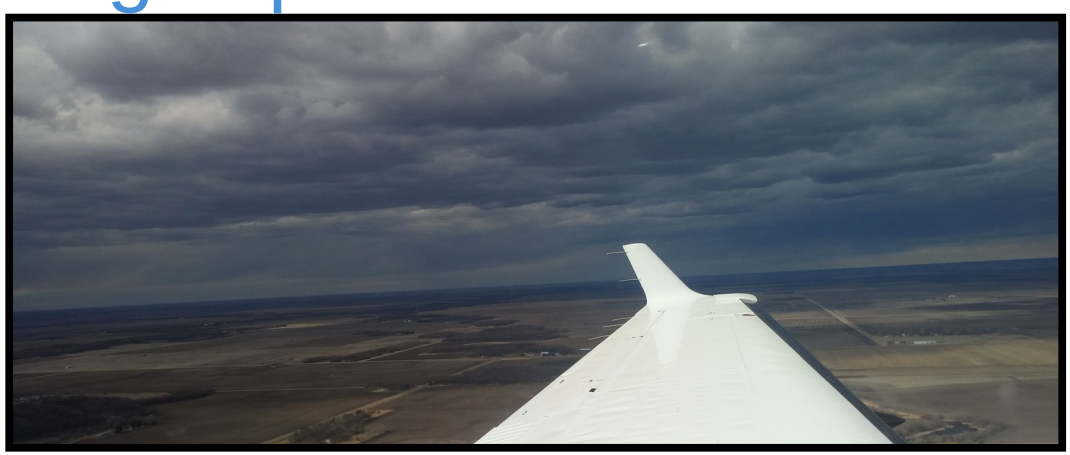
- Data acquisition systems are a difficult and time consuming programming environment.
- Commercially available data acquisition systems are proprietary development environments that do not use open source software.
- There is a limited ability to test processing software since data acquisition systems are specialized computer systems with limited availability.
- Data acquisition systems are not modular data processing environments.
- Reprocessing of data using a data acquisition system is difficult to automate.
- There is absolutely no way of using measurements at a future point in time in a data processing algorithm when processing data in real time

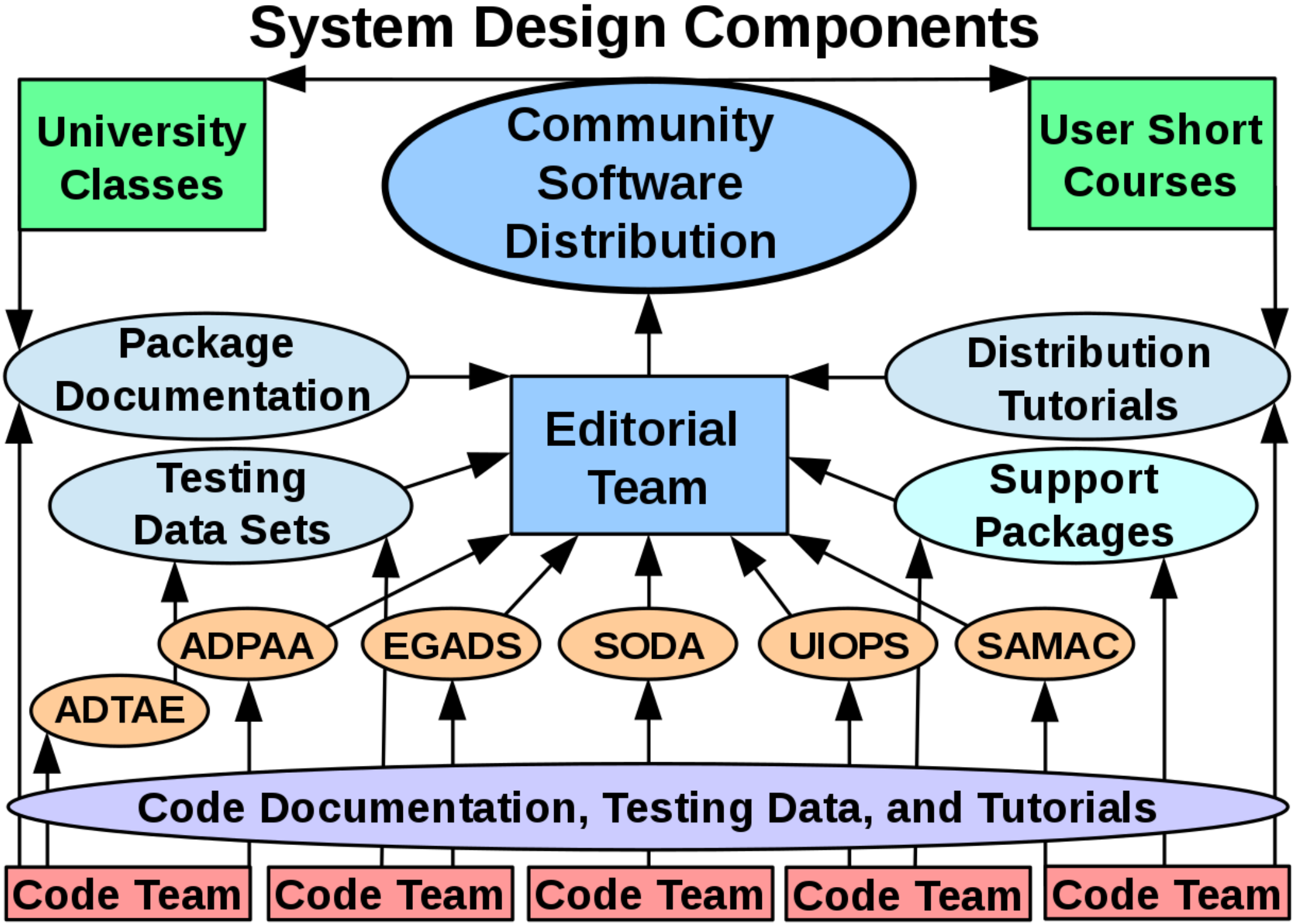
Scientific Programming

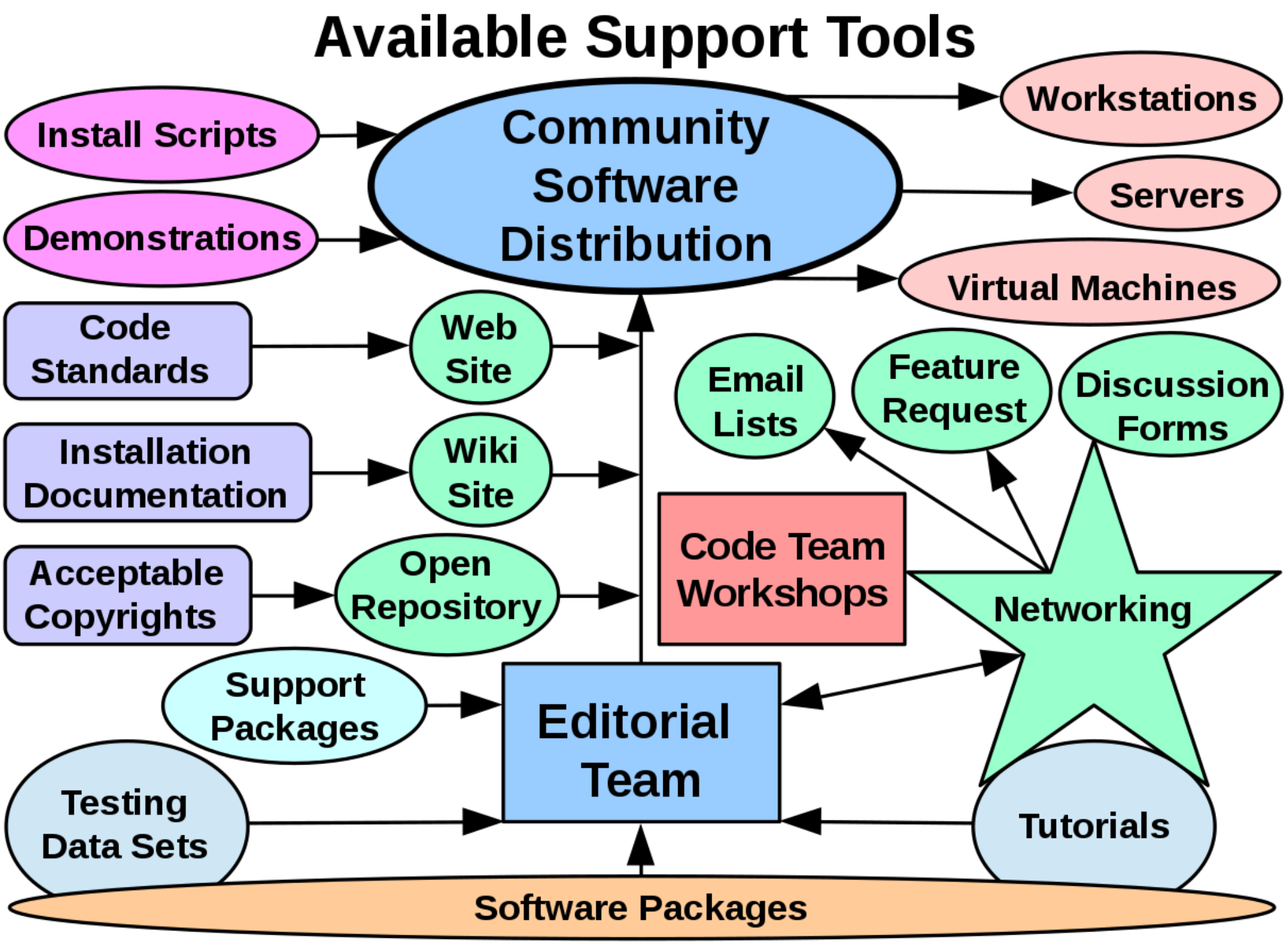
- Scientist write program because they understand the problem to be solved; however, they are judged/reward for writing papers, not producing data sets or software.
- Software used to collect, process and analyze measurements and models almost never evaluated.
  - Sometimes by supervises or co-workers
  - No independent source code review. (Class???)
- Mistakes in software result in wrong scientific conclusions!
  - Black Box / White Box Testing

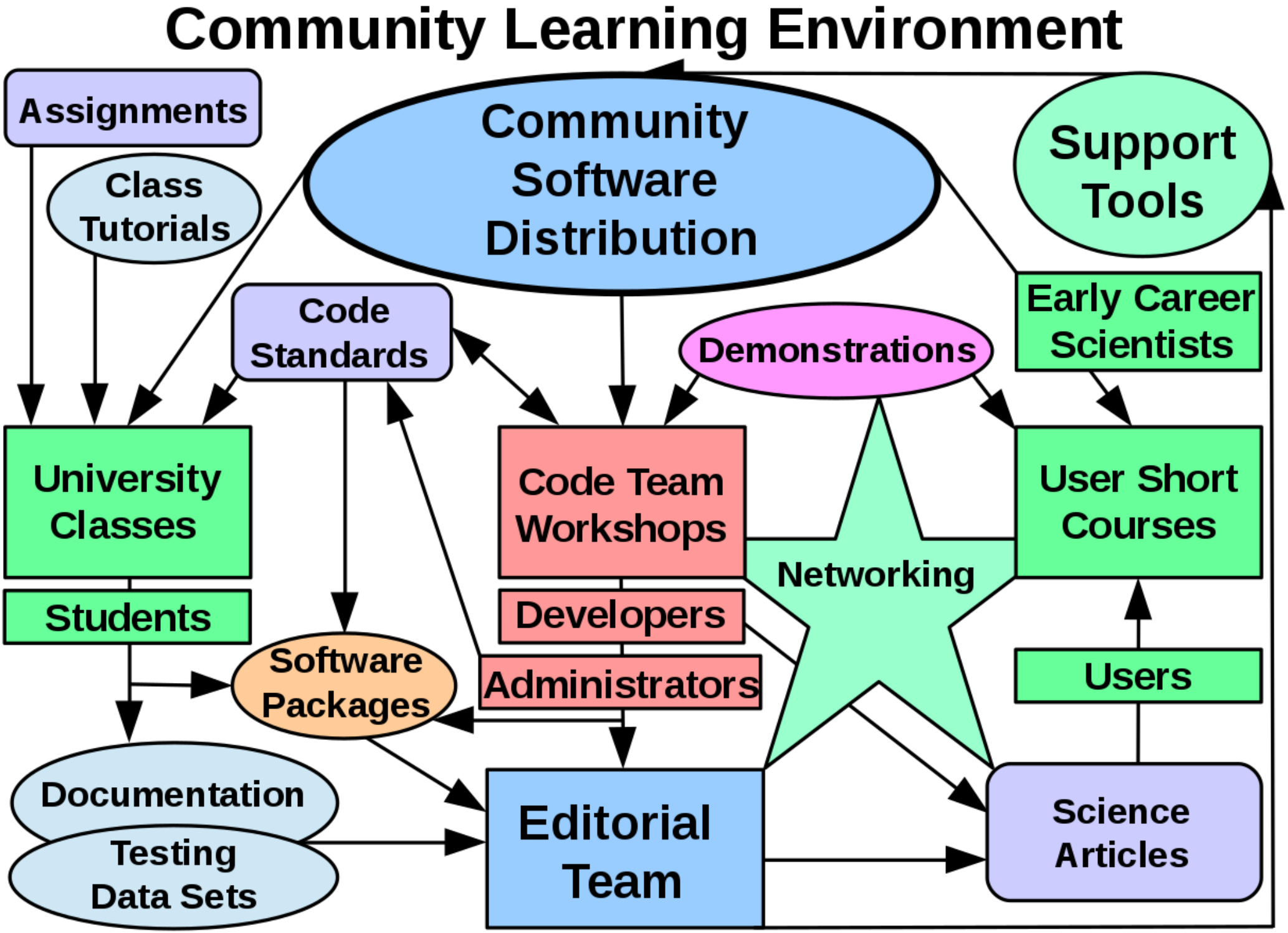
Accuracy of Scientific Results

- Scientist could only reproduce 6 out of 53 “landmark” articles published by reputable labs in top journals.
  - http://www.nature.com/nature/journal/v483/n7391/full/483531a.html
  - http://www.reuters.com/article/2012/03/28/us-science-cancer-idUSBRE82R12P20120328
- John P. A Ioannidis explains how “It can be proven that most claimed research findings are false.”
  - http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1182327/
- Personnel Experience




System Design Components
University Classes
Community Software Distribution
User Short Courses
Package Documentation
Distribution Tutorials
Editorial Team
Testing Data Sets
Support Packages
ADPAA
EGADS
SODA
UIOPS
SAMAC
ADTAE
Code Documentation, Testing Data, and Tutorials
Code Team
Code Team
Code Team
Code Team
Code Team


Available Support Tools
Install Scripts
Demonstrations
Community Software Distribution
Workstations
Servers
Virtual Machines
Code Standards
Web Site
Installation Documentation
Wiki Site
Acceptable Copyrights
Open Repository
Email Lists
Feature Request
Discussion Forms
Code Team Workshops
Networking
Support Packages
Editorial Team
Testing Data Sets
Tutorials
Software Packages

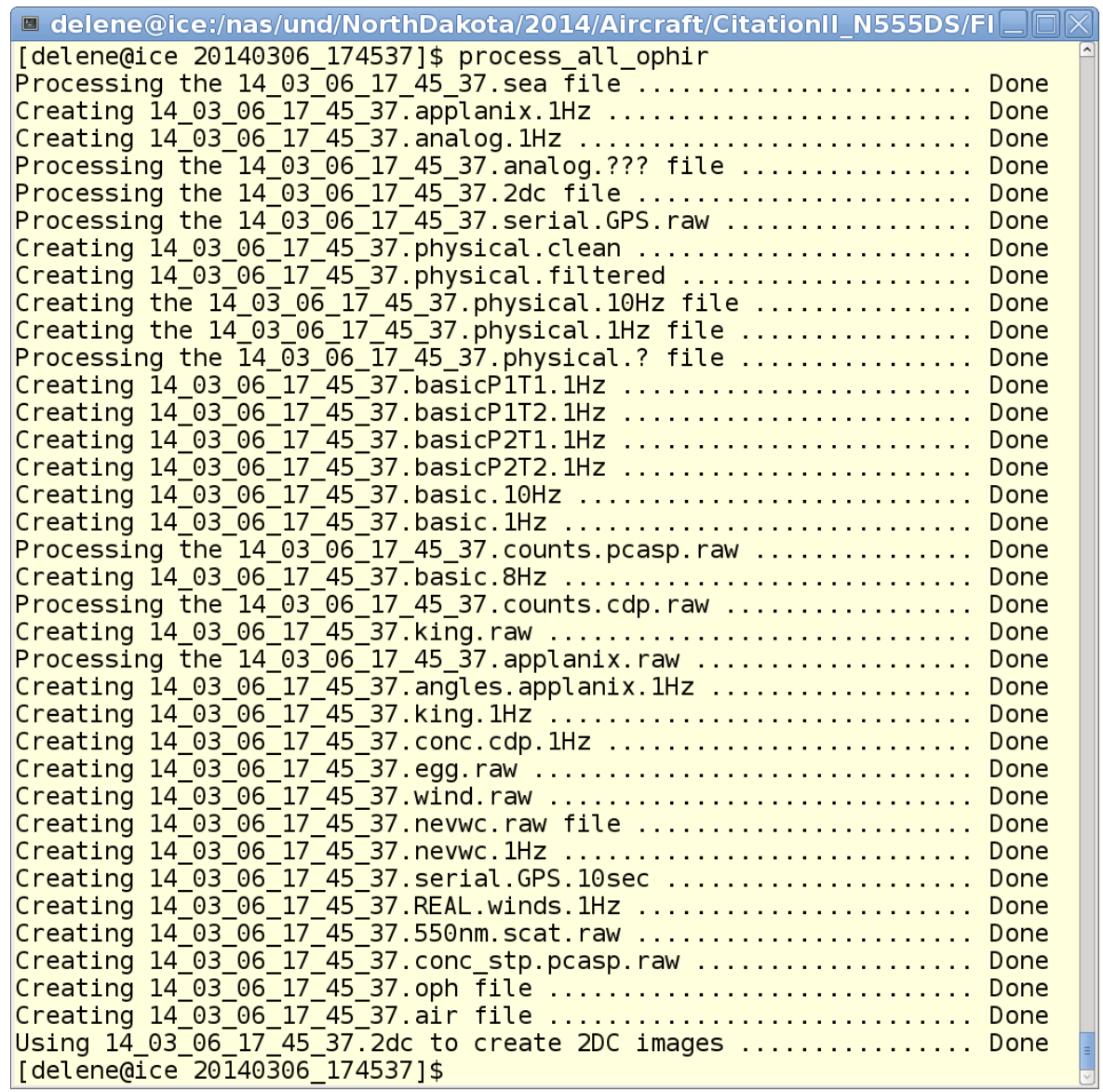

Community Learning Environment
Assignments
Class Tutorials
Community Software Distribution
Support Tools
Code Standards
Demonstrations
Early Career Scientists
University Classes
Code Team Workshops
User Short Courses
Networking
Students
Developers
Software Packages
Administrators
Users
Documentation
Testing Data Sets
Editorial Team
Science Articles

ADPAA Computer Requirements

- Data Processing
  - Flight and Project Processing Scipts
    - Linux (Redhat, Fedora, Ubuntu, Mint)
- Analysis
  - Cplot/Cplot2 Visualization Packages
    - Linux, Mac, Windows

Package Programming Language(s)

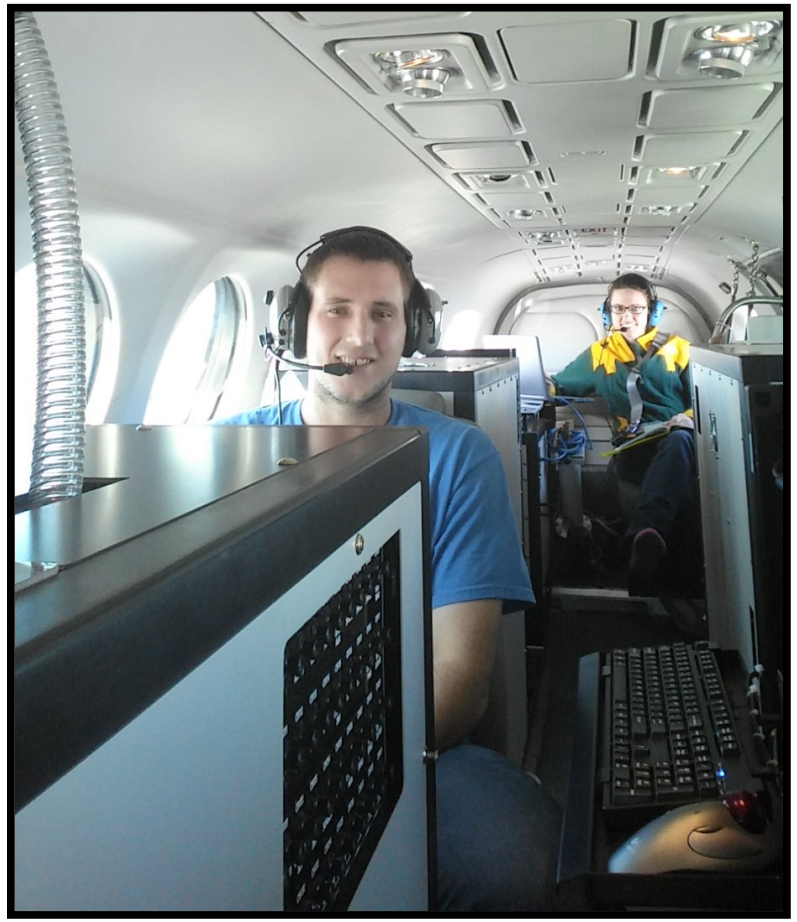
- Main Language
  - IDL (GDL) – Binary Version Available (No License Fee)
- Additional Languages
  - **Python**
  - Perl
  - Bash
  - Csh
  - FORTRAN
  - C
  - Matlab
  - Scilab



Data Formats Supported

- Input from any *.sea acquisition file from the Science Engineering Associates (SEA) Data System
  - Addition Level 1 models could additional data system.
  - Conversion scripts support instrument recorded data.
- Main Data Format
  - Gzipped (compressed) NASA/UND ASCII 1001 Format
- Output Format
  - NASA/UND ASCII 1001 Format
  - 2013 ICARTT NASA Format (ict)
  - NetCDF
  - KML (Google Earth)
- Data File Import Routines
  - IDL, Python, Matlab, Scilab, Igor
- Conversion Routines
  - Too many to list.

Availability and Copyright



- SourceForge Repository (SVN)
  - Current version 3,174
  - 2 Admins
  - 12 Active Developers
  - 6 Inactive Developers
- Download
  - svn checkout

    svn://svn.code.sf.net/p/adpaa/code/trunk adpaa-code
- GNU/GPL v3 Licensed
  - Have to remain open, even when forked.

Data Processing

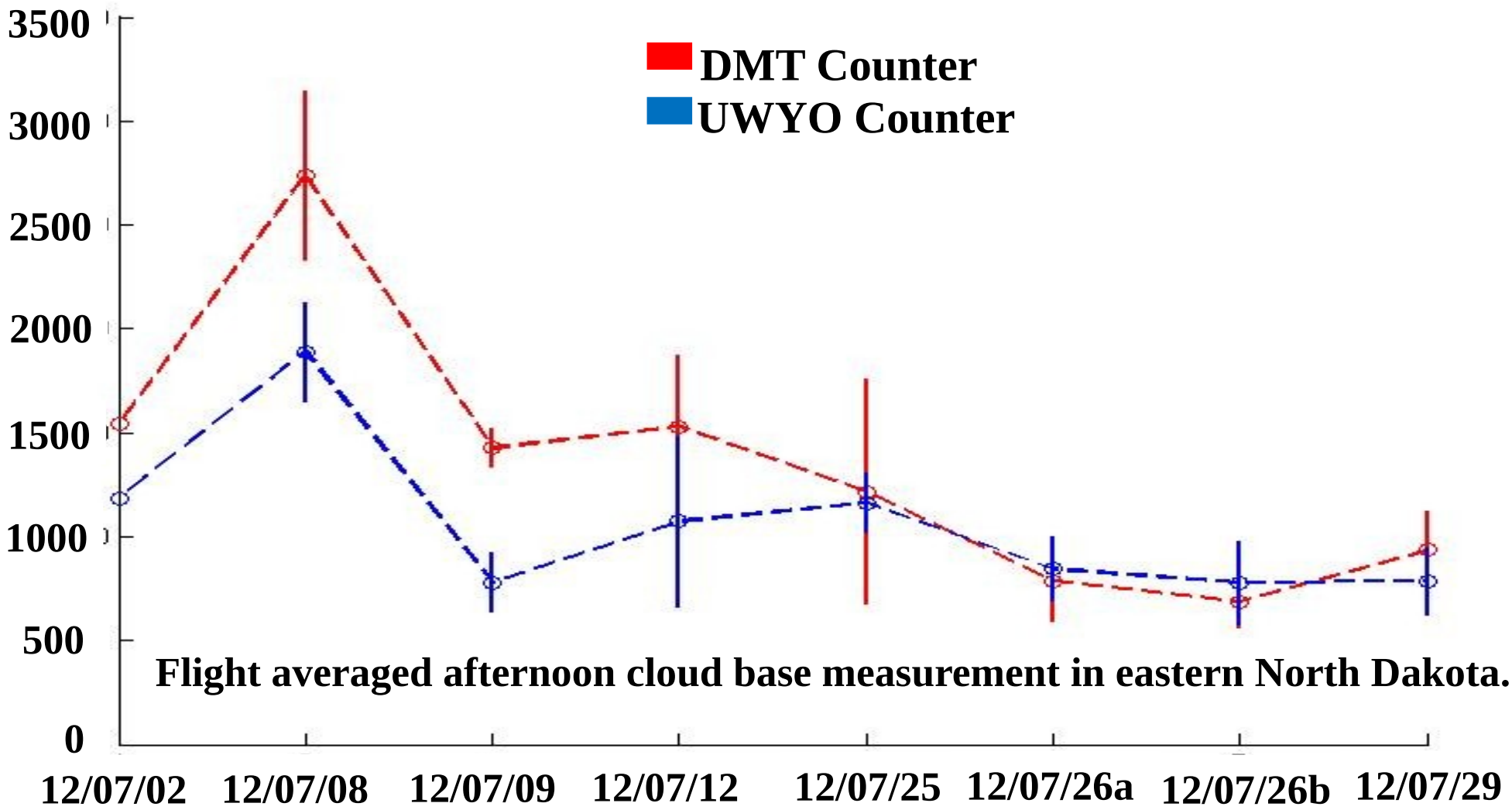
(From 20170404_190617 directory, process_all_kma)

- Data Quality Control
  - Calibration Checks
  - Data Missing Values Codes
  - Levels of Data Processing
  - Raw Recorded Data
  - Engineering to Physical Units
  - Single Instrument Data Files
  - Combined Instrument Data File
- Data Quality Assurance
  - Scientific Data Review
  - Scripts Search for Unrealistic Values

Comments on Scientific Data

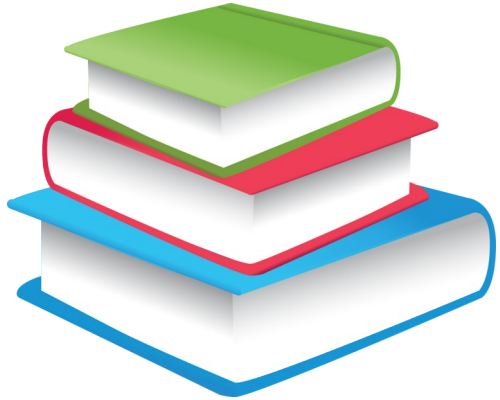
- Quick Visualization of data is very Important.
  - Create a preliminary version of the data using automated processing scripts.
  - Create a final data set after the project is over by applying manual edits to the “raw” data files which replace “bad” data with missing value codes.
- Archive the raw data and any editing files.
- Work with ASCII data as much as possible.
  - Compress ASCII files.
- Use a standard data format, which includes Meta data in all data files.

Scientist Know Calibrations are Important; However, Software Processing can be just as Important



Flight averaged afternoon cloud base measurement in eastern North Dakota.

References: Digital Data



On-line Binary Hex Converters

- http://www.binaryhexconverter.com/

Wikipedia – Serial Port

- https://en.wikipedia.org/wiki/Serial_port#Settings

References: Data Processing

Delene, D. J., Andrea Neumann, Alexei Korolev, Matt Freer, Olivier Henry, Jonathan Crosie, Stephanie Gagne, Landan MacDonald, Aaron Bansemer, Andrew Heymsfield, Colin Gurganus, Ted Fisher, Wei Wu, Greg McFarquhar, Towards Community Software Development to Process and Analyze Cloud Physics In-situ Aircraft Data, Bulletin of the American Meteorological Society, in preparation, 2017.

Delene, D. J., 2016: Airborne Data Processing and Analysis. Source Forge, http://sourceforge.net/projects/adpaa (Accessed January 28, 2016).

Delene, D. J., Airborne Data Processing and Analysis Software Package, Earth Science Informatics, 4(1), 29-44, 2011, URL: http://dx.doi.org/10.1007/s12145-010-0061-4, DOI: 10.1007/s12145-010-0061-4.

Delene, D. J., Suitability of North Dakota for Conducting Effective Hygroscopic Seeding, Journal of Weather Modification, 48, 43-67, 2016.

Web Site - https://sourceforge.net/projects/adpaa/

Wiki - http://adpaa.sourceforge.net/wiki/index.php/Main_Page

Flight Data Post-processing

- Conduct all post-flight processing data starting with the M300 flight data file (*.sea).
  - From 20170404_190617 directory, process_all_kma
- View analog data file in PostProcessing directory, cplot2 17_04_04_19_06_17.analog2.raw