GPM Forum
Mensa in Space
January 11, 2025

Or…Doing It is

Half the Fun

By Don Doerres,
Retired Rocket Scientist
Writer
Mensan Since 1976

Can I Get the Slides?

- Yes
- https://github.com/dondoerres/2025_GPM_by_DRD

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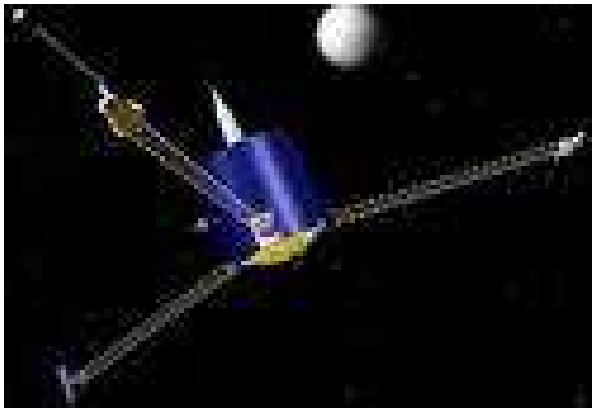
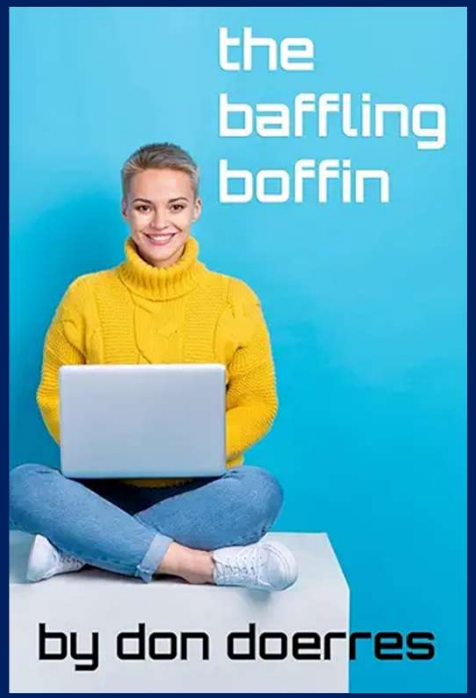
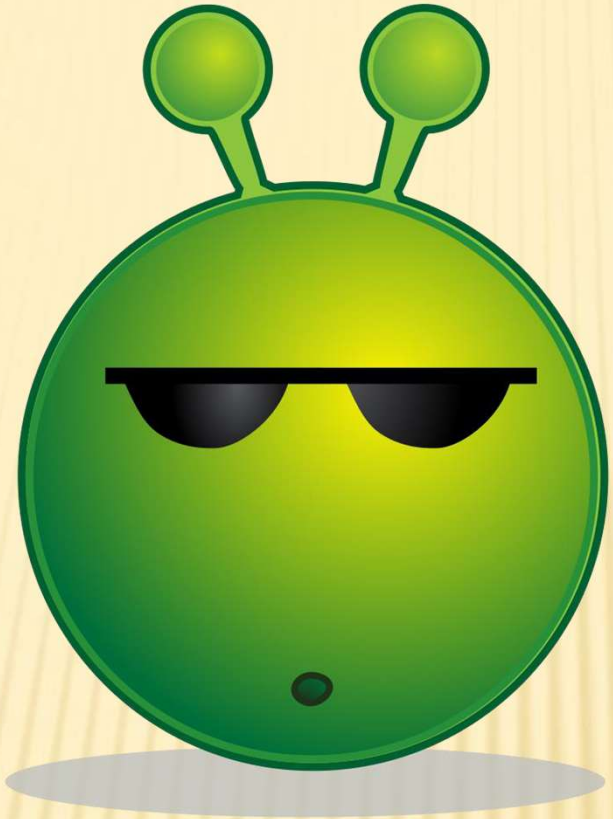




…Book Flog!

The first adventure of
Patricia Boffin is available
from Amazon in
Kindle and Paperback

Tales from the Test Site



First Contact – Life Elsewhere

Originally presented March 15, 2018 to

BIS 402 : LIFE BEYOND EARTH

FUN WITH LUNAR PROSPECTOR…

What Was Lunar Prospector?

- A Little Spacecraft with Attitude
- Part of NASA's Discovery Program
- Well Thought Out, Limited Mission
- Exemplified Epitome of Faster, Better, Cheaper

Still Crazy After All These Years

- A brief history of the mission
- A description of the mission
- A description of my involvement

A Brief History Part 1

- Gerard O'Neill of the Space Studies Institute (SSI) wrote an article in the early 1980's about space exploration and the hope of finding ice on the moon
- At this time NASA was considering unmanned missions to the moon with billion-dollar spacecraft.
- O'Neill said "we wanted the moped of space probes"

A Brief History Part 2

- 1985 the SSI commissioned a study by James French of JPL to see just what a moped satellite could be
- The result of this study was a concept for a $50 million dollar mission carrying just one instrument, a spare gamma-ray spectrometer left over from Apollo days

A Brief History Part 3

- NASA was interested in BIG missions at this time
  - Big missions, Big money
  - Many scientists
- Small missions were ignored by NASA
- At least one private group tried to raise the funds commercially for a moon mission, including Dr. Alan Binder's Lunar Research Institute, about 1988

A Brief History Part 4

- Then came such failures as Mars Observer MOC -- Lost, August 1993

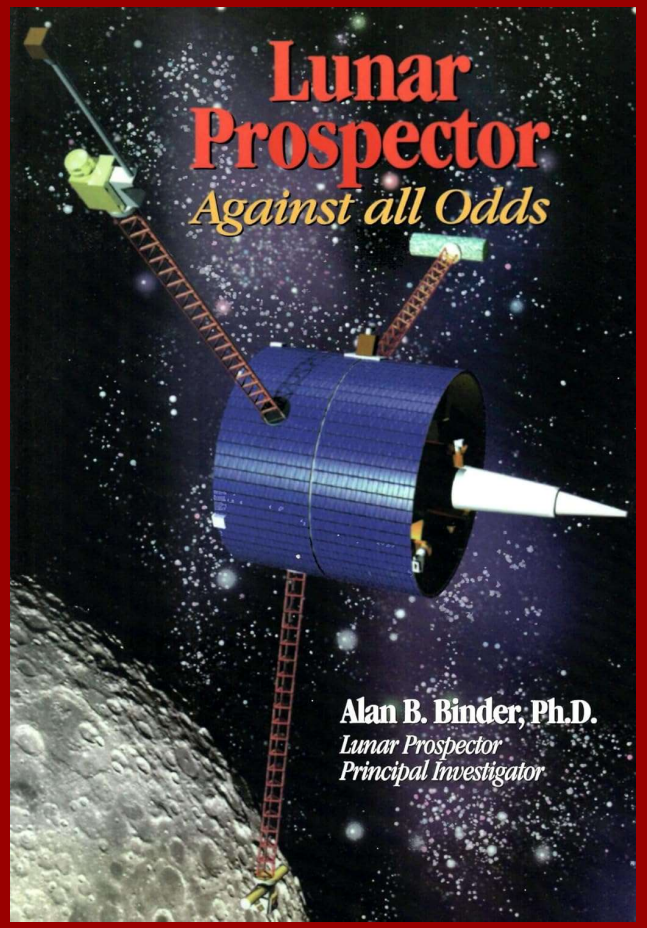
- $1,000,000,000 loss…

A Brief History Part 5

- How about a New Plan?
- Instead of huge spacecraft that do a little of everything – let's have:
  - Small spacecraft that do a few things well
  - Lose one bird, don't lose the whole mission
- Dr. Binder has one…

Alan B. Binder, Ph.D.

- https://www.amazon.com/Lunar-Prospector-Against-All-Odds/dp/1928771319
- Book not for the faint of heart
- Dr. Binder tells all in 1181 pages



Discovery Program!

- The primary goal of NASA's Discovery program is to conduct a series of frequent, highly focused, cost-effective missions to answer critical questions in solar system science. Formally started in NASA's FY 1994 budget, the Discovery program features small planetary exploration spacecraft with focused science goals that can be built in 36 months or less, for less than $190 million in development costs and a total mission cost of less than $299 million.

- The program encourages the use of new technologies, transfer of these technologies to the private sector, increased participation of small and disadvantaged businesses, the pursuit of innovative ways of doing business, and support of the nation's educational initiatives. The objective is to perform high-quality scientific investigations which will assure continuity in the U.S. solar system exploration program and enhance general public awareness of, and appreciation for, solar system exploration.

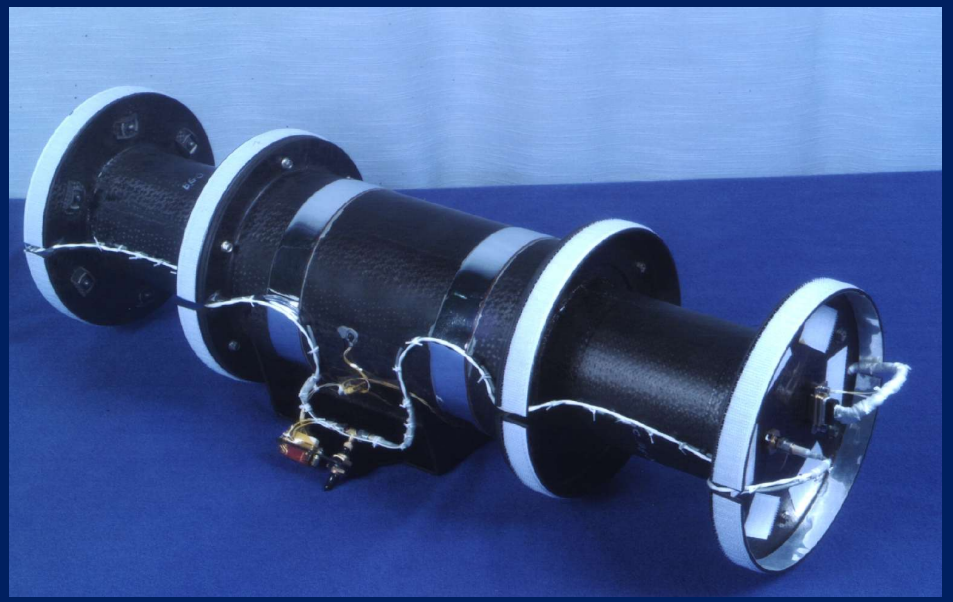
Lunar Prospector

- Six experiments
  - Gamma Ray Spectrometer
  - Neutron Spectrometer
  - Magnetometer
  - Electron Reflectometer
  - Alpha Particle Spectrometer
  - Doppler Gravity Experiment

Lunar Prospector

Gamma Ray Spectrometer

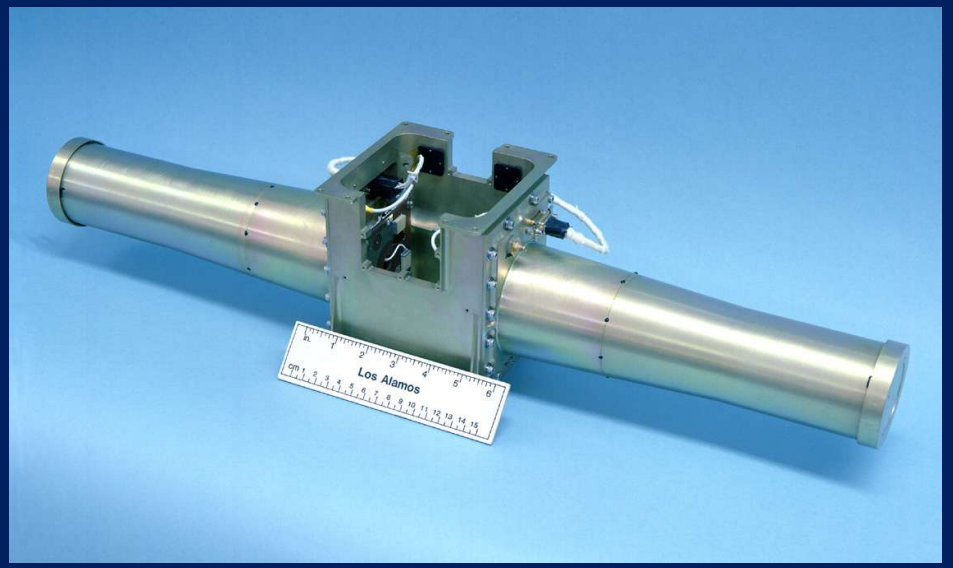
- Sensitive to: thorium (Th), potassium (K), uranium (U), iron (Fe), Oxygen (O), silicon (Si), aluminum (Al), calcium, Ca), magnesium (Mg), and titanium (Ti).
- Especially sensitive to the heavy, radioactive element thorium and the light element potassium.



Lunar Prospector

Neutron Spectrometer

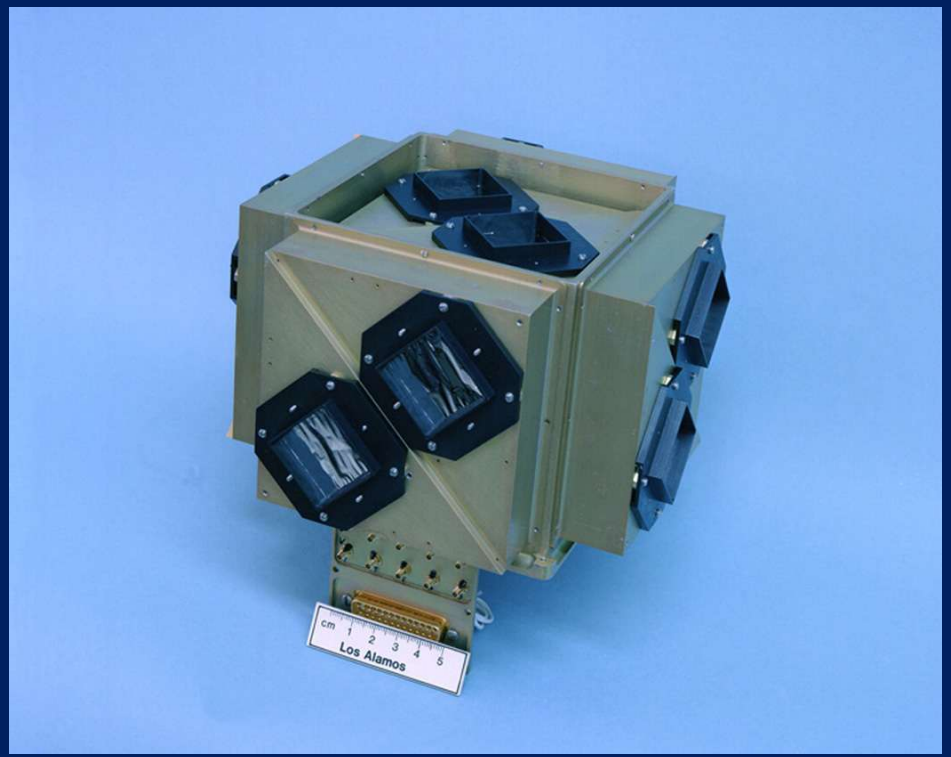
- Worked by detecting hydrogen indirectly by finding neutrons
- Prime mission was to find water, which is indicated by hydrogen



Lunar Prospector

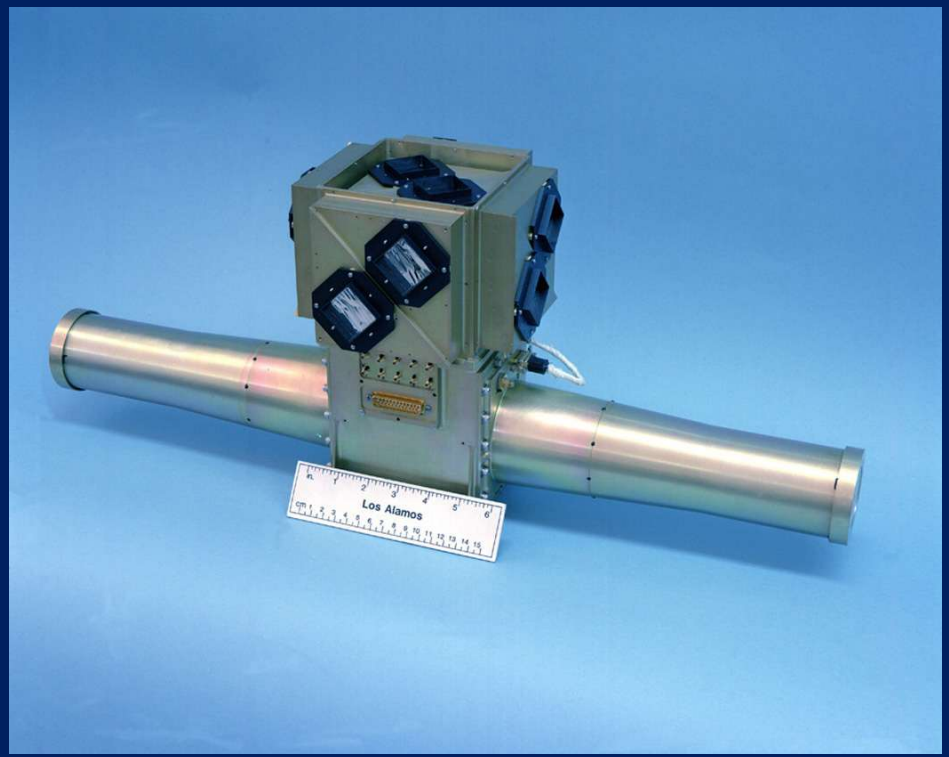
Alpha Particle Spectrometer

- Detected outgassing events on the lunar surface by detecting alpha particles from radon gas and its decay products



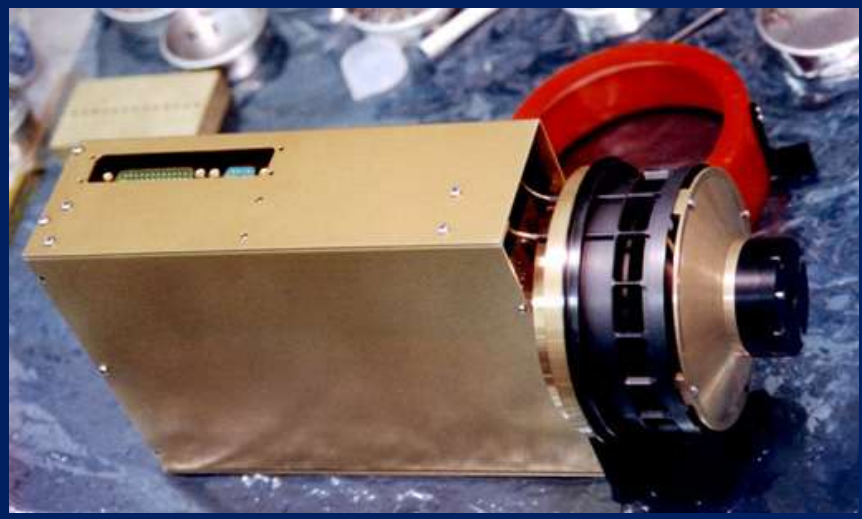
Lunar Prospector

Alpha Particle Spectrometer and Neutron Spectrometer mounted together



Lunar Prospector

Electron Reflectormeter



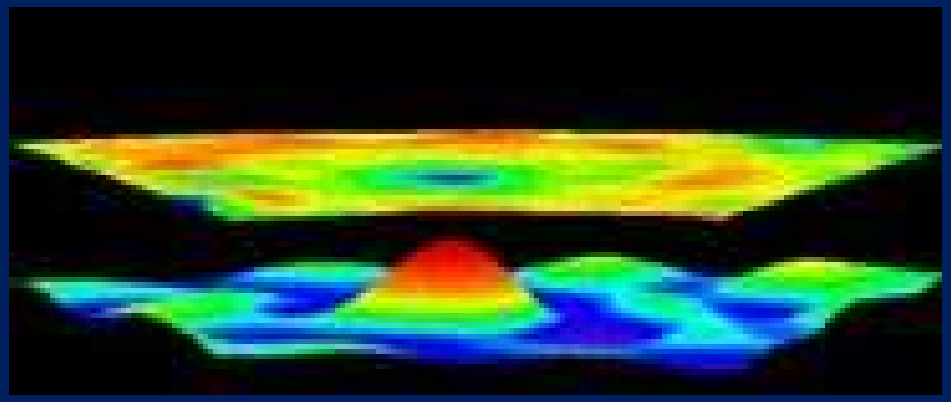
Magnetometer

- Returned data on the lunar crustal magnetic field and the lunar induced magnetic dipole; mapped localized magnetic fields

Lunar Prospector

Doppler Gravity Experiment

- Used doppler tracking of the S-Band radio signals broadcast from the spacecraft (actually, the telemetry signal from the spacecraft) to characterize the orbit of the spacecraft and the lunar gravity field



Where I Come In…

- In 1996 Spectrum Astro was awarded the Command and Data Handling (C&DH) contract for Lunar Prospector from Lockheed/Martin, the Prime Contractor

- I was responsible for all software development for the C&DH and for key parts of HW/SW partitioning

Let's Have Some Fun…

- The "standard approach" Costs Too Much
- What are the alternatives?

Let's Have Some More Fun…

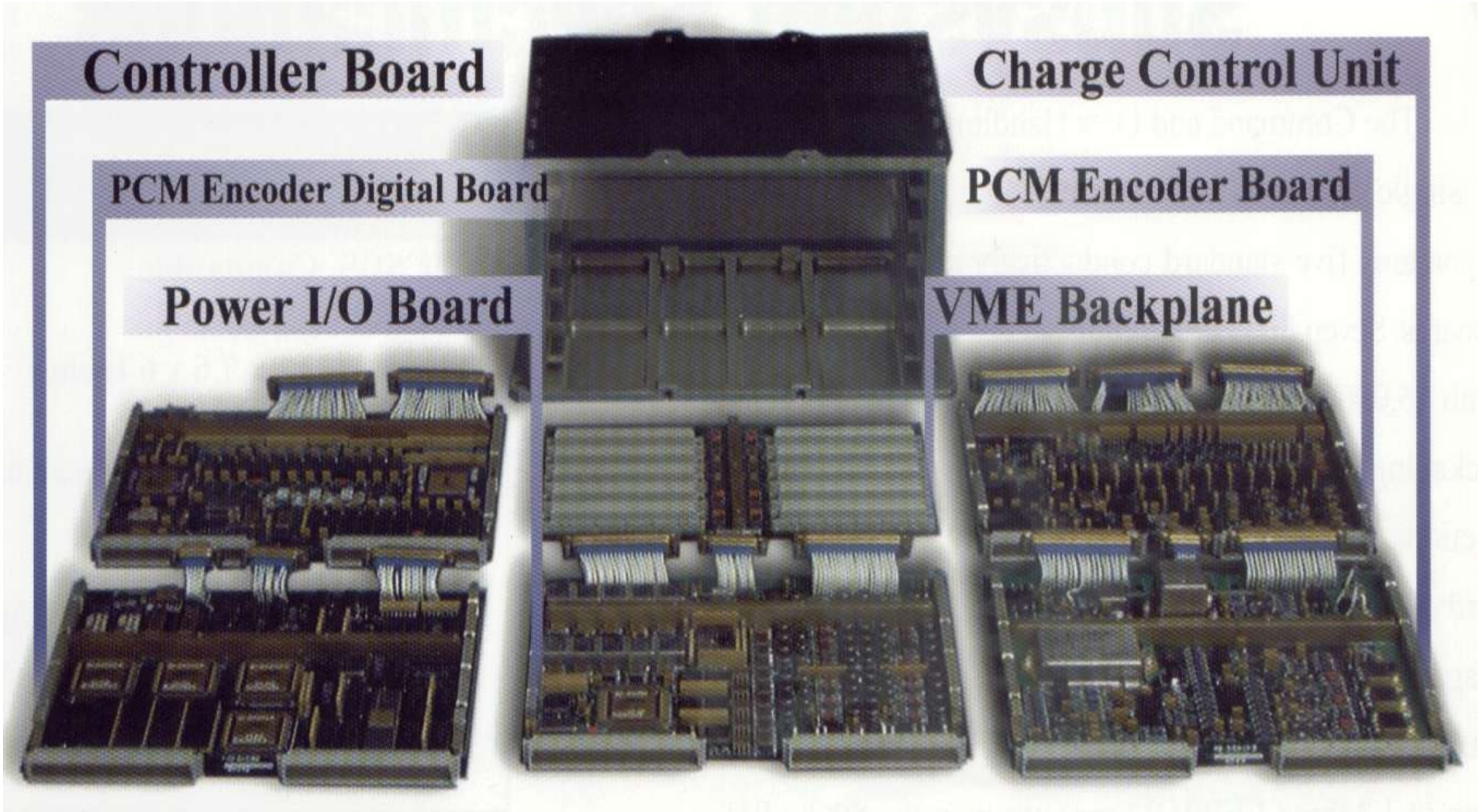
- Instead of a large team, how about a tight knit, small group with one person in charge of each key activity?

- What do we have we can already use?

Hardware Software Partitioning

- Software is good at:
  - Complicated Sequences
  - Doing things up to a moderate rate of speed
  - Doing integer math
- Hardware is good at:
  - Simple Sequences
  - Doing very simple things very fast
  - Doing simple logic (and, or, negate…)

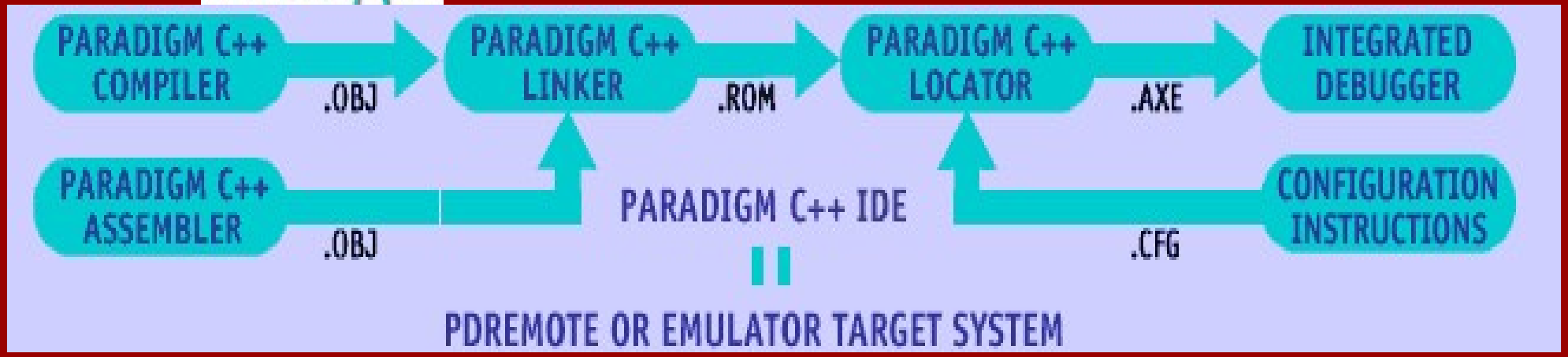
Lunar Prospector C&DH



Software Tool Cost-RTOS

Description	Lead Time/By	Qty	Cost/Ea.	Total Cost
Tornado 2.0 w/ SlickEdit and ScopePak		1	$5,495.00	$5,495.00
Tornado Annual support		1	$1,105.00	$1,105.00
VxWorks		1	$14,000.00	$14,000.00
VxWorks Annual Support		1	$2,550.00	$2,550.00
VxWorks 5.x Block Target License		2	$700.00	$1,400.00
			PO Total:	**$24,550.00**

Software Tool Cost-RTOS



$995.00 complete.

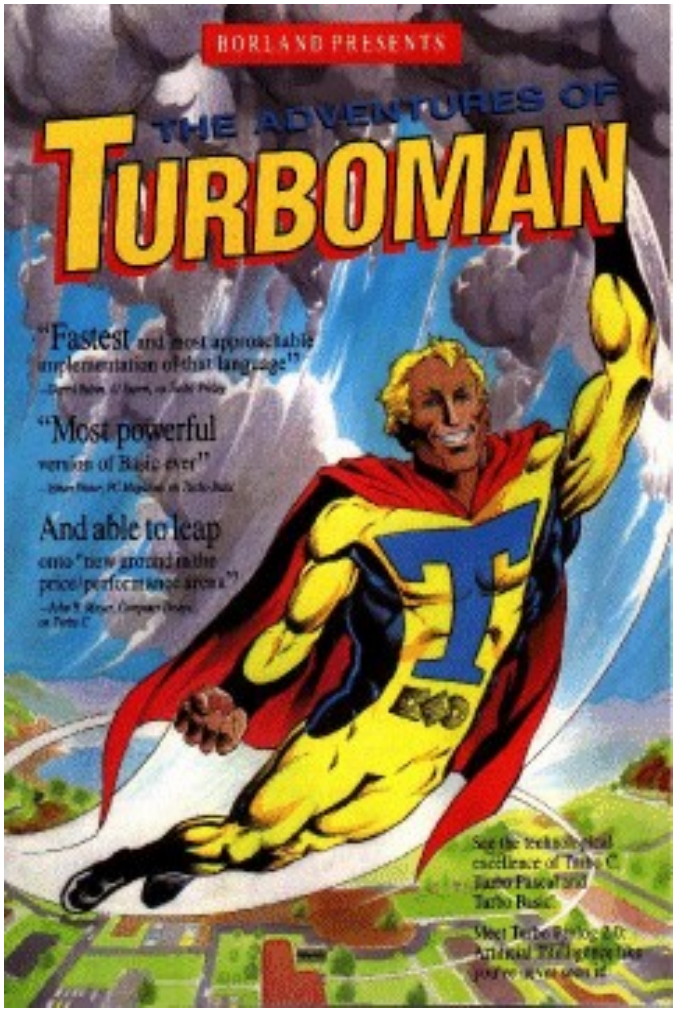
Unlimited target licenses.

Software Tool Cost-Compiler

Description:	Quantity	Price:	Total:
MULTI Programming Env	1	$ 7,900.00	$ 7,110.00
Annual Maintenance	1	$ 1,580.00	$ 1,422.00

Software Tool Cost-Compiler

$39.95 plus $5 shipping & handling!



The Software

- 1783 lines of ‘C’ in 11 months.
- One byte of included assembler: 8086 IRET instruction for unassigned interrupts

The Software

- No libraries included (no stdio.h, no stdlib.h, no math.h…nothing but raw C!)
- All integer (16 bit) math
- Seventeen ‘.C’ source files, one ‘.asm’ file

The Software

- Usual start up code
  - CPU wake up
  - Hunt for console input
  - Jump to flight code
- High level startup
  - Set up CPU interrupts
  - Initialize globals
  - Setup VME I/O space
  - Setup hardware circular queue
  - Run forever loop

The Software

- Command handling
  - CCSDS
  - Fixed length commands
  - Verify on ground, then Execute
- Telemetry
  - CPU built frames
  - Data stuffed into a FIFO for downlink—FIFO 4 words deep

Software Results

- No anomalies
- No reboots
- No VME bus errors
- Few Operational problems
  - Commanding in low Signal/Noise due to moon bounce
  - “Engineering mode” (default and diagnostic mode) never used in flight— experimenters later said they would have preferred to never include it since mission was so flawless

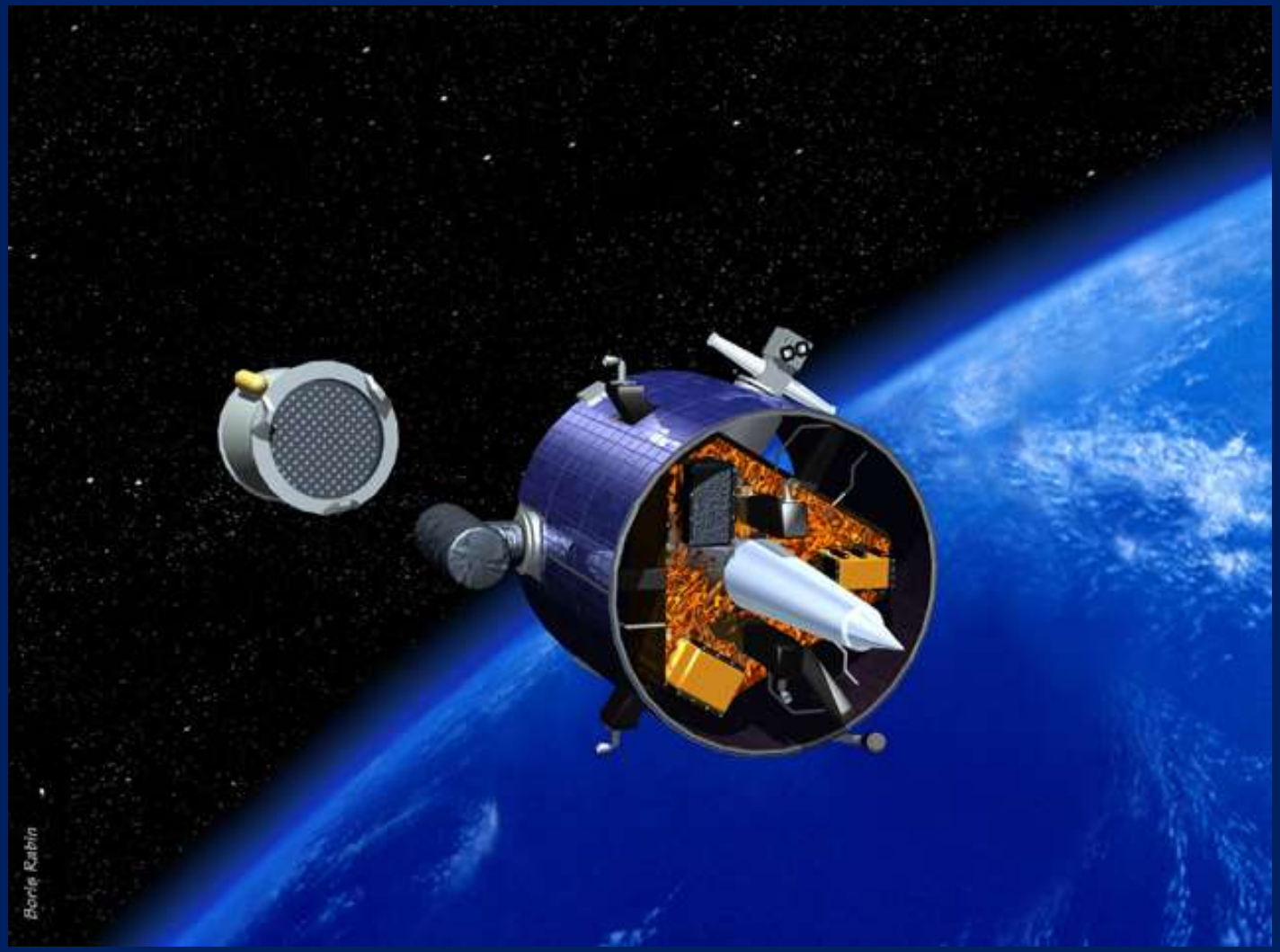
Building It Up

Mounted on Kick Motor

Ready…

Go!

Separation…



In Orbit

Length of Mission

Actual

Anticipated

RIP Lunar Prospector

Favorite Lunar Links

- http://nssdc.gsfc.nasa.gov/planetary/discovery.html
- https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=1998-001A
- https://science.nasa.gov/mission/lunar-prospector/
- https://en.wikipedia.org/wiki/Lunar_Prospector

MY VIEWPOINT

- There's gotta be somebody out there
- I'm still waiting…and watching
- Isaac Asimov's *Foundation* doesn't have anybody out there
  - All **seven** books of the Foundation **Trilogy** put humans in an almost empty universe -- for our own good, of course
  - I really prefer lots of friendly aliens – and these we have, at least in imagination

ENGINEERS AND SCIENTISTS

Engineers

- What and how questions
- Work for the material benefit of humanity

Scientists

- Why questions
- Work to understand the world we live in

Most mad scientists are really mad engineers

Scientists and Engineers often swap roles

- Applied science
- Research engineer

THREE POINTS IN 20 MINUTES

1. Earth's first space man
2. A different view of Drake's Equation
3. Outreach to aliens – Deep Space 1

EARTH'S FIRST SPACE MAN

Fair Use for Educational Purposes claimed

- Adam Strange, of course:

https://www.geekhistorylesson.com/episodes/ghl-311-adam-strange-with-tom-king-mitch-gerads-amp-doc-shaner

DRAKE'S EQUATION
N = R X FP X NE X FL X FI X FC X FL

- N = number of alien civilizations in (i.e., *across*) the Milky Way
- R = number of stars in (i.e., *through*) our galaxy
- fp = Fraction of stars with planets
- ne = number of planets where life as we know it can exist
- fl = % of those planets where life arises
- fi = % of those planets (fl) where intelligence develops
- fc = % of those societies that develop electromagnetic science
- fL = % of societies that emit electromagnetic signals into space for a long time

Note: Dr. Drake (1930-2022) was a professor at UC Santa Cruz.

DRAKE'S EQUATION AS YOU HAVEN'T SEEN IT

- E = I * R

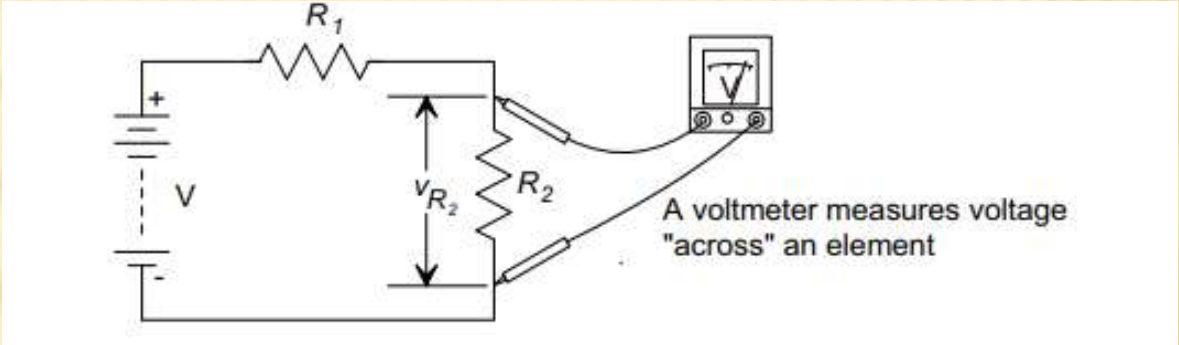
The generic relationship between a through and an across variable where:

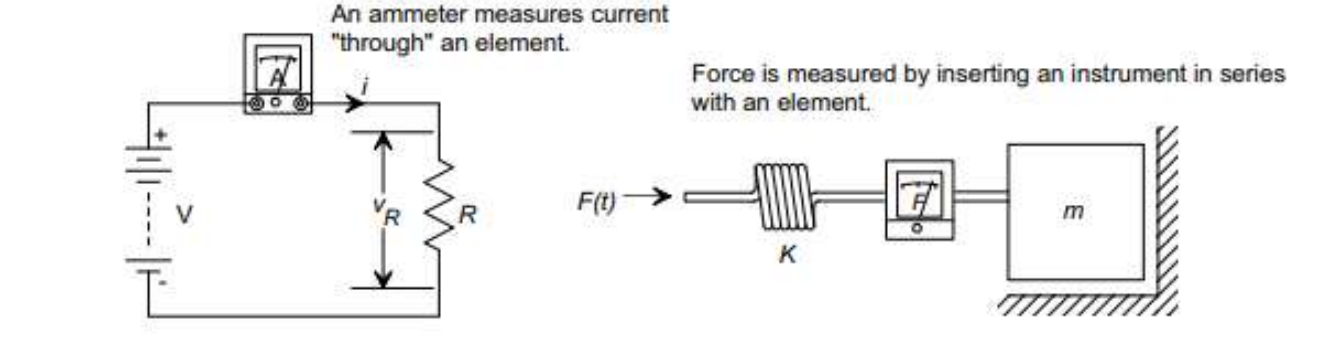
E = generic across variable

I = generic through variable

R is a constant of proportionality

ACROSS AND THROUGH





THROUGH AND ACROSS VARIABLES

- Through variable has value transmitted through an element
- Across variable value is determined by measuring a difference of the values at two extreme points of an element
- Through and Across variables are related by a Constant of Proportionality

EXAMPLES FROM "REAL LIFE"

- Pressure equals density times height
  - P = H * D
  - Water pressure increases the deeper you go
- Force equals displacement times a constant
  - F = K * X
  - Amount of force required to stretch a spring is a constant times the amount you stretch it
- Force equals mass times acceleration
  - F = M * A
  - Pulling "G's" when you accelerate your car

A LITTLE MATH RAZAMATAZ

- N = R * fp * ne * fl * fi * fc * fl
  - Let N = E, the across variable
    - Let R = I, the through variable
    - Let the proportionality constant be

      fp * ne * fl * fi * fc * fl = R
- Substituting:
  - E = I * R
- The point is...just see what we can do with simple math

SIMPLE MATH

- E=IR
  - I=E/R
  - R=E/I
  - P = E*I or the product of the through and across is “power” in physics.
  - What might “Power” mean with respect to inhabitable planets?
  - **Is “The Force” real?**

FUN WITH FIGURES

- Given N:
  - How many intelligent species have been in television shows that are long running?
  - How many species are intelligent?
  - Just how many stars are there in the galaxy(ies)?
  - If I know the through variable, then I can figure the across variable by algebra.

A REAL OPPORTUNITY TO SEE THE FUTURE

- Usually, we can only guess
- This is a rare occasion when you can see the future from a point in the past

Ready?

OUTREACH

- Most spacecraft carry a greeting from earth
- Consider the gold record on Voyager I and II

Fair Use for Educational Purposes claimed

- All of the infrared spectrometers from the ASU SESE carry a plaque with the signatures of everyone on the project

NOTE: My name is out there!

THE DEEP SPACE 1 CD

- Certainly less publicized than the Voyager record
- The spacecraft actually carried three or four different CD's and DVD's literally sewn into the thermal blanketing.
- These were from various groups associated with the project

Image courtesy NASA

THE DS1 CD

I was responsible for putting together a CD from the prime spacecraft contractor, a company called Spectrum Astro (later General Dynamics C4, later General Dynamics IS, later Orbital Sciences, later Orbital ATK, later Northrup Grumman…)

MORE DS1 CD

- The DS1 contained comments from anyone on the mission interested in making them
- Young people from Boys and Girls Clubs all over the world were invited to convey in pictures and words what they thought the future would bring.
- The pictures are 27 years old now.

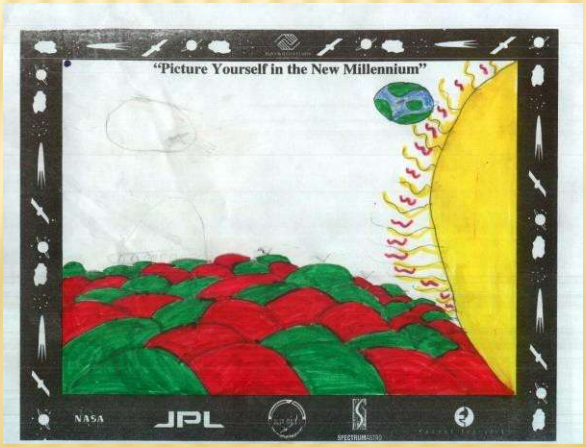
WHAT CAN YOU DO WITH THE DS1 CD?

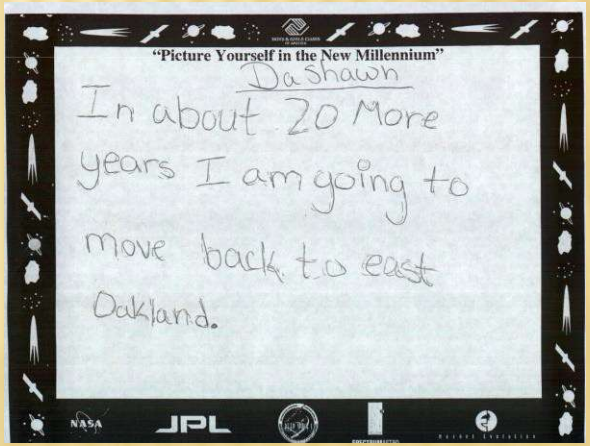
- First, get one:

https://www.slideshare.net/dondoerres

https://github.com/dondoerres/DS1_CD

- Then reflect:
  - *What was the vision of the future 27 years ago?*
  - Hundreds of young people shared their vision by sending it into deep space.
  - Have a look…





The Truth is Out There

Questions?