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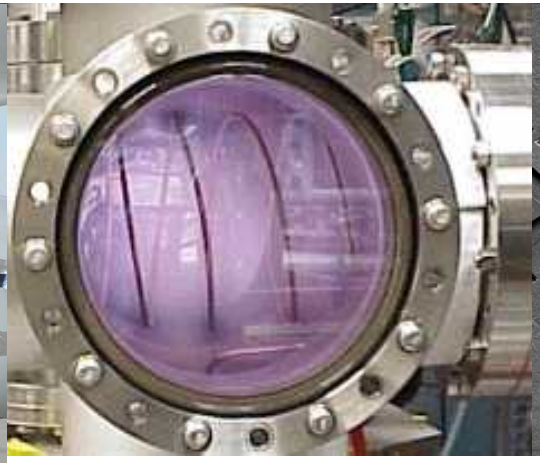

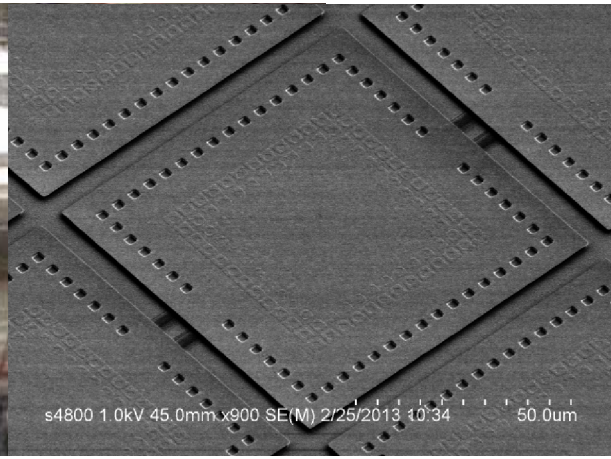

Space Sensor Commercialization – A small company approach

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U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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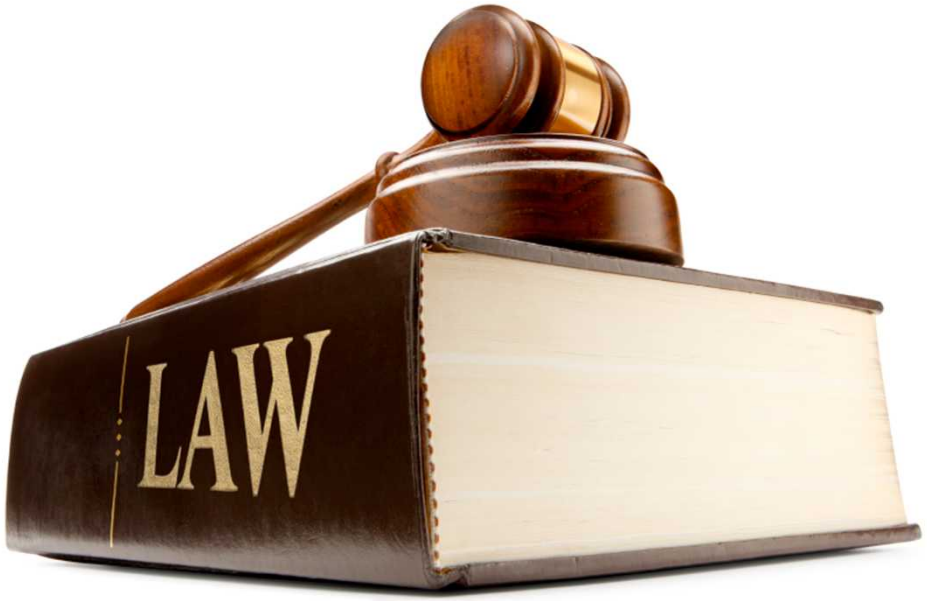
For the lawyers (we know you're out there)

- This discussion regards work previous to my tenure at Sandia, and is all open in nature (and classification) and not encumbered by any agreements. This is my personal view and history of space sensor commercialization and not that of Sandia National Labs.



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AeroAstro – quick intro

- Small satellite company manufacturer
  - STP-SAT I
  - STP-SAT II
  - SMARTBus
  - Bitsy, Alexi, Terriers, HETE, etc
- While CTO there, biz case encouraged me to set up a new division “CTS - Components, Technology, and Sensors”
  - 8% Fee on govt and university contracts is not exciting nor sustainable
  - Satellite contracts are few and far between
  - Satellite sensors are used by a larger pool that just AeroAstro for tis own satellite buses
  - We priced as FFP items, and maintained healthy margins
- Eventual customers included
  - LM, Ball, Orbital, NASA, AFRL, MIST, Singapore Nat’l University, etc

What Components? What Sensors?

- Imager family of products
  - Miniature Star Tracker
  - Miniature Imager
  - RSO detector
- Sun sensors
- X-band transponders
- S-band Radios
- “Technologies” were the combinatorial use of these in new ways

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How did we get there?

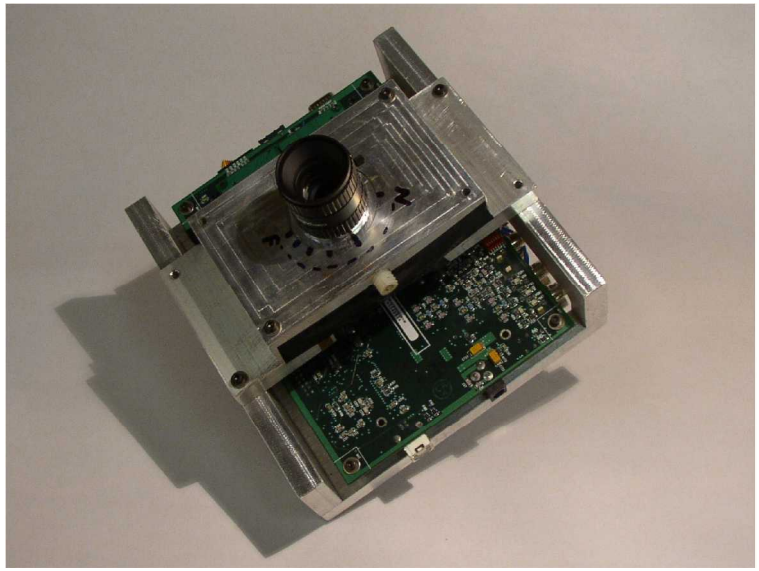
- Space Sensors need qualification
  - No one wants to risk their space mission on “unproven” components
- Catch-22
  - Can’t get to space unless you have already been there!
- NASA TRL levels (Mankins, 1996) provide a way
  - TRL-4 – Component/Breadboard validation in laboratory environment
  - TRL-5 - Component/Breadboard validation in relevant environment
  - TRL-6 - System/subsystem model or prototype demonstration in a relevant environment (ground or space)
- Time to be creative
  - What about just “kissing” space?

“Kissing space”?

- Why?
  - We had already performed T-vac, shake/rattle/roll testing…but there is nothing like the real thing!
  - What about 5-10 minutes in space?
  - Remember the bathtub curve
- Launch, operation, retrieval of sensors after working on suborbital launches provide
  - Real environment
  - Extra testing (shock from takeoff and retrieval)
  - Hard to argue real data!
- Who launches suborbital craft?
  - A friend of mine – Jerry Larson of UP Aerospace

What are we talking about?

- AeroAstro Miniature Star Tracker
- Engineering Development Unit
- Testbed for algorithms
- Generate customer interest / input
- Flight verification



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Miniature Star Tracker

- Flight Prototype (mockup)
- Microspace market generation
- Penetration of “big space” as low $$ backup
- Deliveries of breadboard units continue, protoflight orders have been placed

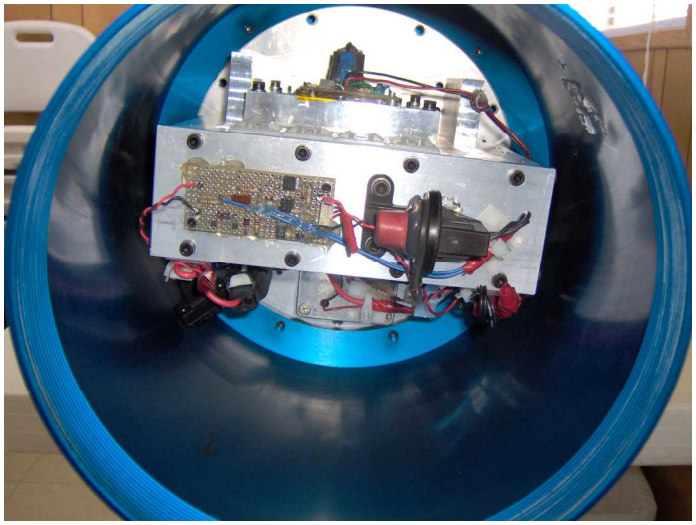
AeroAstro

Why do this?

- Need for microsat star tracker "obvious" *(after 10 years promoting it)*
  - Low size (2" x 2" x 3")
  - Low weight (< 300g)
  - Low power (~ 2W)
  - Decent performance:
    - 70 arc-seconds (or better) attitude in all 3 axes
    - Lost-In-Space
    - Update rate ~1 Hz
  - $125-150k single unit cost

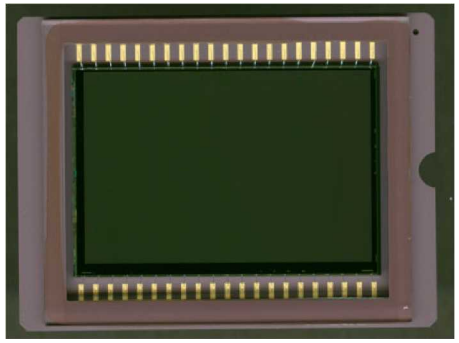
Launch!

- MST-Breadboard
  - Pressure Switch and G-Switch
  - Sits in nosecone
  - Take pics of artificial stars
    - Test Algorithms
    - Get space “time”
  - Recover Compact Flash with data
  - Analysis of data



AeroAstro

Keep it Simple!



- Requirements Formulation
  - As low as possible!
    - 30 deg FOV
    - Look for bright stars (mag 4.5)
    - Single threaded app
  - Fewer parts = more robust (diesel vs gas)
    - Use CMOS imager
    - Fewer external support parts
  - Reliability without $$-parts

Star Tracker	Goodrich HD-1003	Ball CT-633 (601)	SODERN SED-16	Galileo AA-STR	AeroAstro MST
Size (cm)	41 x 16 x 11	34 x 19 x 19	29 x 17 x 16	18 x 12 x12	**5 x 8 x 8**
Mass (kg)	3.54	2.85	3.0	1.1	**0.3**
Power (W)	10	10 (12)	12.8	3.8	**~2.0 W**
Cost ($k)	550	> 600	> 500	~ 300	**<150**
Accuracy (arcsec 3ó)	5	40 (5)	70	98	**~ 70**

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Post-commercialization

- What are your goals?
  - Will you be making these devices 10 yrs from now?
  - Who will service them?
- What are company goals?
  - Short term strategy – survival
  - Mid-range strategy - growth
  - Exit strategy? Complete exit or component exit?
- Are your personal goals aligned with company goals?

Some other things to consider

- Funding – especially venture - can take a long time to materialize
  - It's not a free check - you will have a board, and funding parameters often progress from yearly to mile-stone based (short-leash)
- Funding – govt especially – has lots of paperwork and govt PMs – even your champions - can change often
- Who owns what?
  - Venture/Investors
  - Govt
  - Company

Whatever happened to AeroAstro?

- With the other officers and upper managers, we sold the company to Radyne Corp (SatCom) for 18M
  [Good IP story there if you are interested...]
- Part of my contract was to stay on 1 yr as part of transition
- Much of the transition team (including myself) left at this 1-yr point
- Two years later Radyne sold AeroAstro to ComTech
- About a year after that, AeroAstro shut down (2012), only surviving assets - being CTS (my original division!) – components build plans & supplier list sold to Space Micro
- NB: The Sensors Survive!