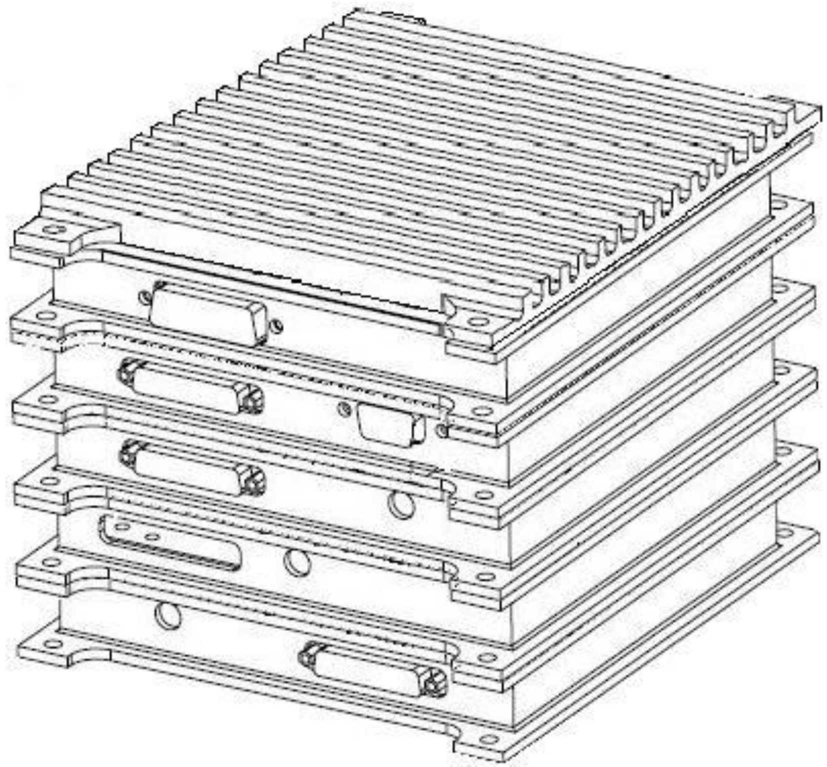
National Aeronautics and Space Administration

PULSAR SDR

Programmable Ultra Lightweight System Adaptable Radio

Software Defined Radio

August 12, 2013



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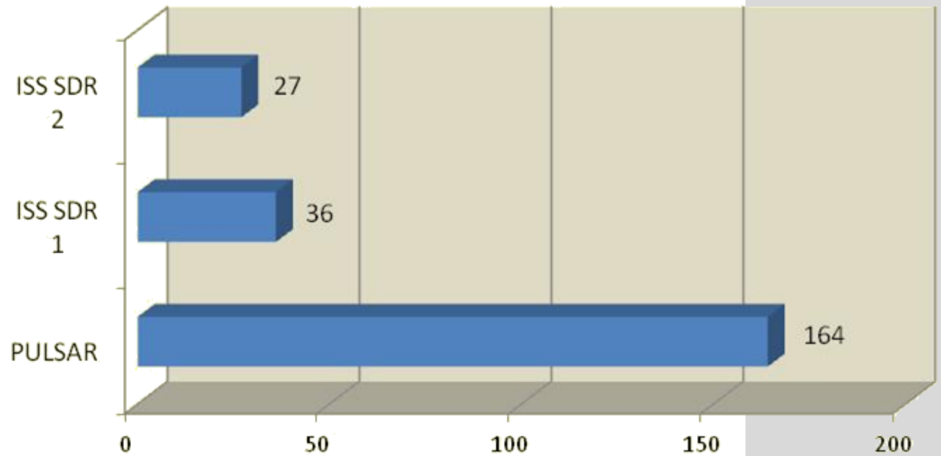
Design Objectives

- **Optimize SWaP**
  - Reduce Size — *~ 1U & 2.2 kg#*
  - Reduce Power — *< 15W*
  - Reduce Part Count — *SDR*
  - Reduce Complexity
  - Increase Capability — *150Mbps*
  - Increase Reliability
- **Adaptive to Requirements**
  - Multiple Permutations of Processing, Receiving, and Transmitting
  - 3 Forward Error Correcting Options*
  - 2 Phase Modulation Options
- **Address NASA Roadmap Objectives**
  - Communications and Navigation (TA05)
  - Higher data rates (OCT Objectives B & C)
  - Information Technology (TA11)
  - Strategic Goals (3, 5, and 6)



High Definition Pictures Transmitted, # per minute

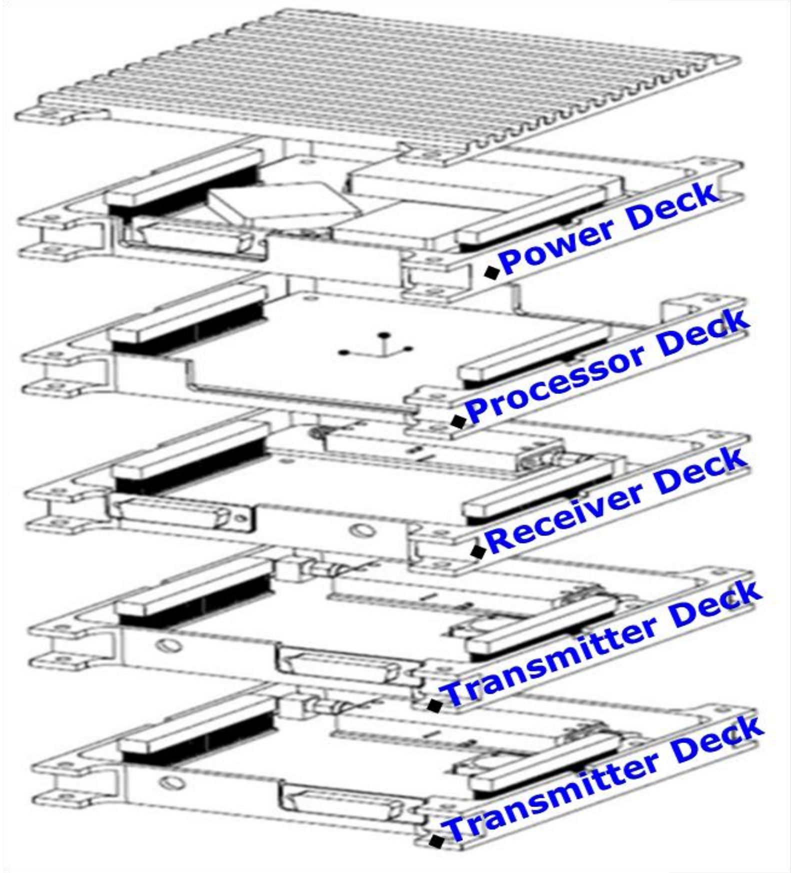
Technology	Old Method	PULSAR
Ranging	Tone	Doppler Shift
Processing	Processor	FPGA
Transmission	Sub-carrier	Direct on Carrier
FEC	Reed-Solomon	LPDC

FEC – Forward Error Correcting
FPGA – Field Programmable Gate Array
ISS – International Space Station
kg – kilogram
LDPC – Low Density Parity Correcting
Mbps – Megabits per second
PULSAR – **P**rogrammable **U**ltra **L**ightweight **S**ystem **A**daptable **R**adio
OCT – Office of Chief Technologist
SDR – Software Defined Radio
SWaP – Size, Weight, and Power
U – 10 x 10 x 10cm

* - More FEC options available on request
\# - Current SDR on the ISS is 6.6 kg with data rate at 32 Mbps

FY2013 Significant Milestones

- **Leveraged Flight Heritage Hardware (Generation 1)**
  - FASTSAT Communication System
  - Components on orbit for over two years
- **Formulation/Peer Review (02/2013)**
- **Hardware Procurement (04/2013)**
- **"Hardware In the Loop" Validation (08/2013)**
  - S-Band Transmitter uses < 12 watts
  - X-Band Transmitter uses < 15 watts
  - Data rates
    - » 500 Msps (~445 Mbps) bench testing
    - » Regulated to 150 Mbps to work with NEN
    - » Capability for both S- & X-Band
- **HEROES Balloon Flight (09/2013)**
  - Non-critical Payload
  - TRL 7 for Sub-orbital Flights

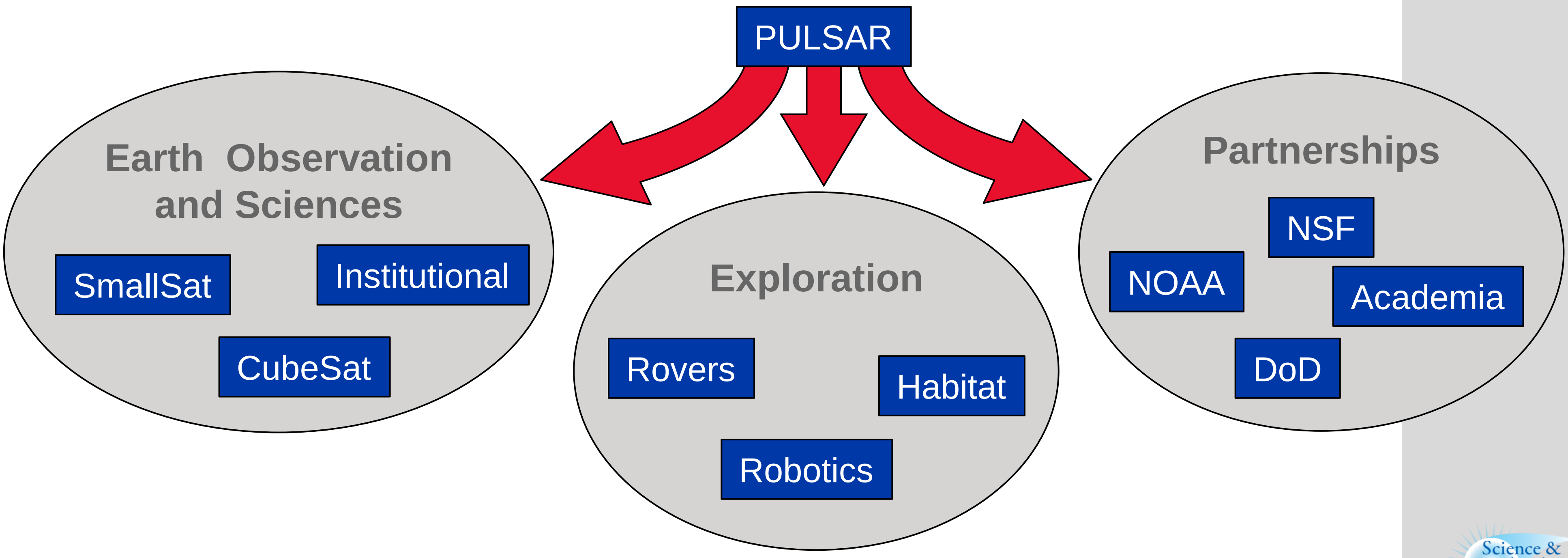


PC104+ type stackable connectors

Mbps – Mega bits per second
Msps – Mega symbols per second
NEN – Near Earth Network
TRL – Technology Readiness Level

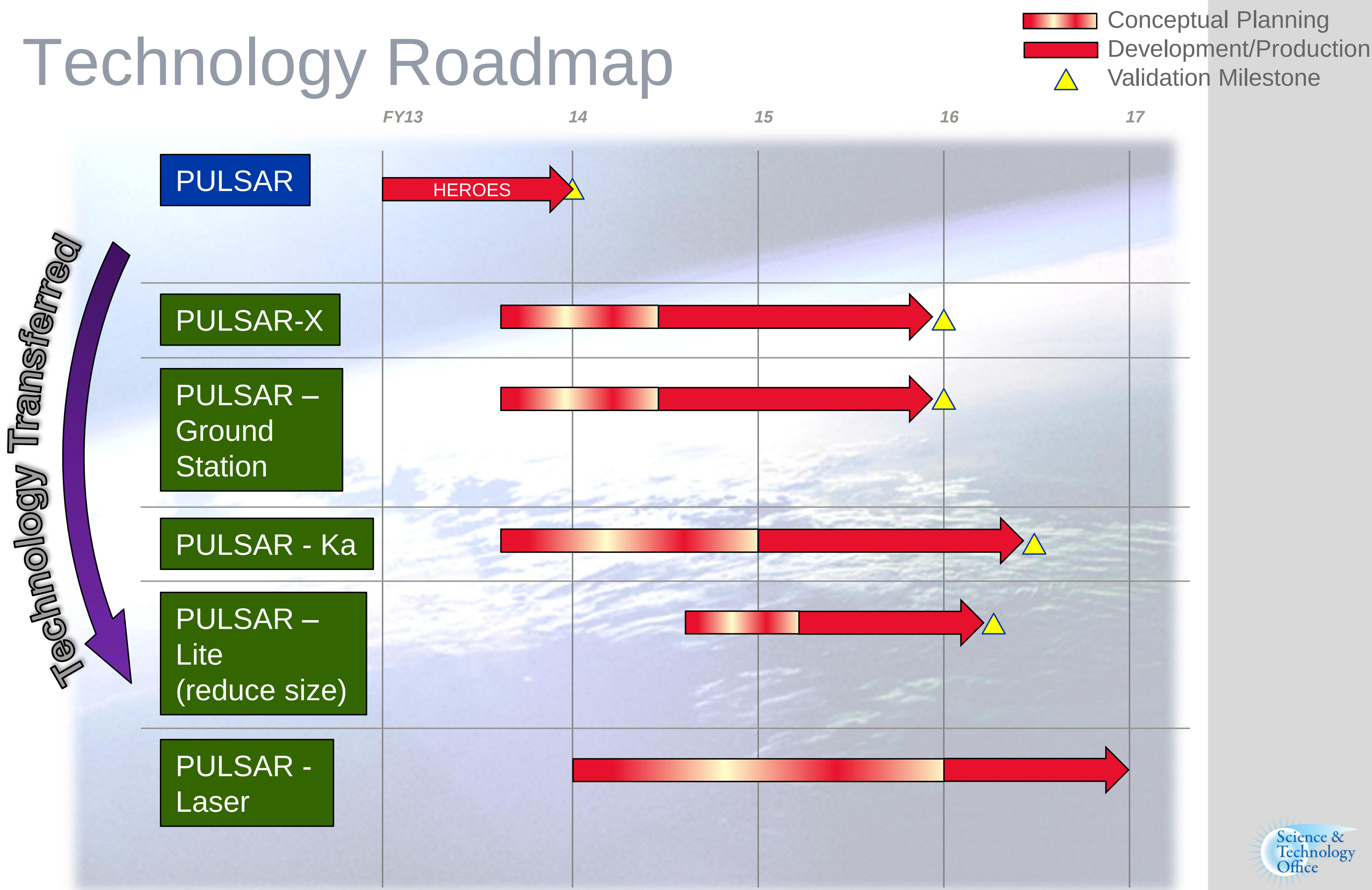
Comparison and Infusion

				Data Rate				Benchmark		
Manufacturer	Frequency	Input		Uplink	Downlink	Mass	Cost	Rcvr	Trx	
	Band	V DC	W DC	kbps	Mbps	kg	$k	b/W	b/W	Notes
MSFC PULSAR	S-, X-	28	15	300	445	2.1	55	20,000	37,083,333	LDPC, 10.8 x 10.8 x 9.8 cm
GD (derived from StarLight)	S	28		72	10				1,000,000	SCaN Testbed, reprogrammab
JPL (derived from Electra)	S	28	82	769	10	6.6		51,267	1,000,000	SCaN Testbed, reprogrammab
Harris Corporation	Ka	28	100	25000	100	19.2			2,500,000	SCaN Testbed, Convolutional,



$k,M –	US Dollar, thousand, Million	kbps –	kilobits per second	Rcvr –	Receiver
b/W –	bit per Watt	kg –	kilogram	Trx –	Transmitter
in –	inches	Mbps –	Megabits per second	W –	Watt

Technology Roadmap

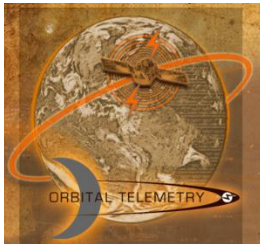


Summary

- **PULSAR Design Success**
  - Reduces SWaP
  - Increases Data Rates
  - Adapts to Program Requirements
  - Meets NASA Roadmap Objectives

- **Baseline Technology Provides Pathway to Further Advances**

- **License Agreement for Technology Transfer**
  - Orbital Telemetry of Huntsville Alabama



kg – kilogram
PULSAR – **P**rogrammable **U**ltra **L**ightweight **S**ystem **A**daptable **R**adio
SWaP – Size, Weight, and Power

NASA

Appendix A – PULSAR SDR

Acronyms

References

NASA Technology Area & Strategic Goals

Technology Levels

Potential Customers

In-Kind Letters

Backup Slides

Acronym Listing *(Enlarged)*

$k,M –	US Dollar, thousand, Million
b/W –	bit per Watt
FEC –	Forward Error Correcting
FPGA –	Field Programmable Gate Array
in –	inches
ISS –	International Space Station
kbps –	kilobits per second
kg –	kilogram
LDPC –	Low Density Parity Correcting
Mbps –	Mega bits per second
Msps –	Mega symbols per second
NEN –	Near Earth Network
OCT –	Office of Chief Technologist
PULSAR –	Programmable Ultra Lightweight System Adaptable Radio
Rcvr –	Receiver
SDR –	Software Defined Radio
SWaP –	Size, Weight, and Power
TRL –	Technology Readiness Level
Trx –	Transmitter
U –	10 x 10 x 10cm
W –	Watt

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References

- **NPD 1001.0A, 2011 NASA Strategic Plan**
- **NASA Strategic Roadmap Summary Report; May 22, 2005**
- **NASA Space Technology Roadmaps and Priorities - Restoring NASA's Technological Edge and Paving the Way for a New Era in Space**
- **Space Telecommunications Radio Systems (STRS) Architecture Standard (previously NASA/TM-2010-216809)**
- **MSFC-STD-3663, MSFC Standard for Configurable Logic Device Developments**
- **NPR 7150.2, NASA Software Engineering Requirements**
- **MPR 7150.2, MSFC Software Engineering Requirements**
- **Technology Readiness Levels; http://www.hq.nasa.gov/office/codeq/trl/trlchrt.pdf**
- **NASA Engineering Network, Program/Project Management Community; https://nen.nasa.gov/web/pm**

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PULSAR Matches NASA Technology Areas

- **Communication and Navigation Systems (TA05)**
  - "As is indicated in the roadmap, there are several communication and navigation technology development efforts that will directly benefit currently planned missions. Of the developments directly applicable to planned missions Low Density Parity Coding (LDPC) and a 15 w Ka-band Solid State Power Amplifier (SSPA) would improve mission performance as would the development of Software Defined Radio (SDR) technology for the next LEO standard S-band transceiver and the Universal Space Transceiver (UST) operating in Ka-band.
  - As depicted in the TASR, early RF communications development will focus on development of a reprogrammable software defined radio that can then be used as an infusion path for subsequent developments. The mid-term focus is on reducing SWAP for major components.
    - » SWAP = Size, Weight and Power
- **Modeling, Simulation, Information Technology, and Data Processing (TA11)**

2011 Strategic Goals Synchronized to PULSAR

- **Strategic Goal 3: Create the innovative new space technologies for our exploration, science, and economic future.**
  - Sponsor **early-stage innovation in space technologies in order to improve the future capabilities** of NASA, other government agencies, and the aerospace industry.
  - Infuse **game-changing and crosscutting technologies** throughout the Nation's space enterprise to transform the Nation's space mission capabilities.
  - Develop and demonstrate the critical technologies that will make NASA's exploration, science, and discovery missions **more affordable and more capable**.
  - **Facilitate the transfer of NASA technology and engage in partnerships** with other government agencies, industry, and international entities to generate U.S. commercial activity and other public benefits.
- **Strategic Goal 5: Enable program and institutional capabilities to conduct NASA's aeronautics and space activities.**
  - Ensure vital assets are **ready, available, and appropriately sized** to conduct NASA's missions.
  - Ensure the availability to the Nation of **NASA-owned, strategically important test capabilities.**
  - **Implement and provide space communications** and launch capabilities **responsive to existing and future science and space exploration missions**.
  - **Establish partnerships**, including innovative arrangements, with commercial, international, and other government entities to maximize mission success.
- **Strategic Goal 6: Share NASA with the public, educators, and students to provide opportunities to participate in our Mission, foster innovation, and contribute to a strong national economy.**
  - **Inform, engage, and inspire the public by sharing NASA's missions, challenges, and results.**

Emphasis added to show areas of synergy

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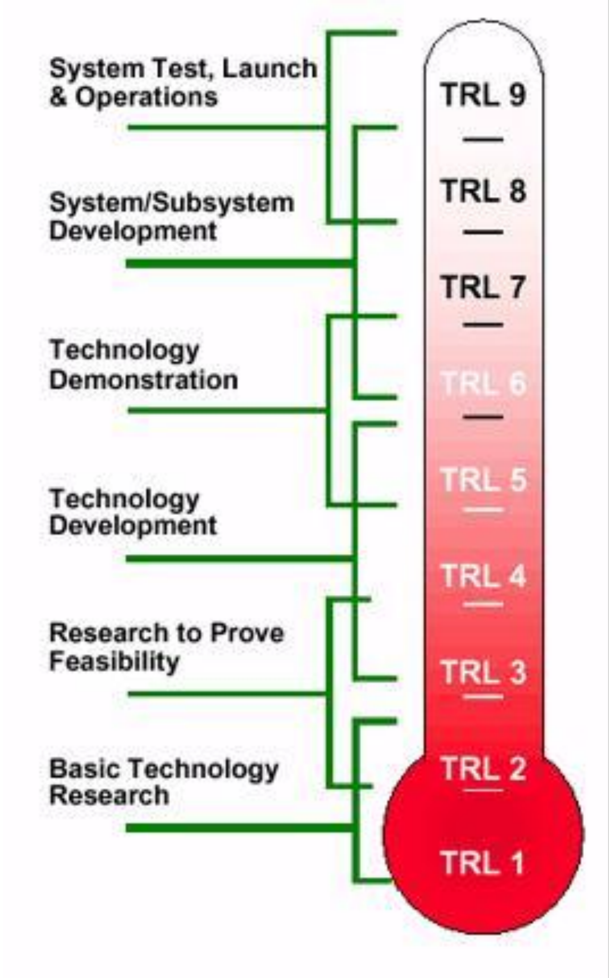
Source: 2011 NASA Strategic Goals, NPD 1001.0A

Technology Readiness Levels

- **NASA defines TRL 5 as**
  - *"A medium fidelity system/component brassboard is built and operated to demonstrate overall performance in a simulated operational environment with realistic support elements that demonstrates overall performance in critical areas. Performance predictions are made for subsequent development phases."*
- **NASA defines TRL 7 as**
  - *"A high fidelity engineering unit that adequately addresses all critical scaling issues is built and operated in a relevant environment to demonstrate performance in the actual operational environment and platform (ground, airborne, or space)."*



NASA Missions

- **High Energy Replicated Optics to Explore the Sun (HEROES)**
- **Warm Gas Test Article (aka Mighty Eagle)**
- **Marshall Airborne Polarimetric Imaging Radiometer (MAPIR)**
- **Autonomous Missions**
- **Robotic Missions**
- **Small Satellites and Spacecraft**
- **Advanced Exploration Systems (AES)**

Fig. 2. MAPIR enclosed in fairings beneath a Piper Navajo.

Credits: Photos taken from individual project presentations and websites

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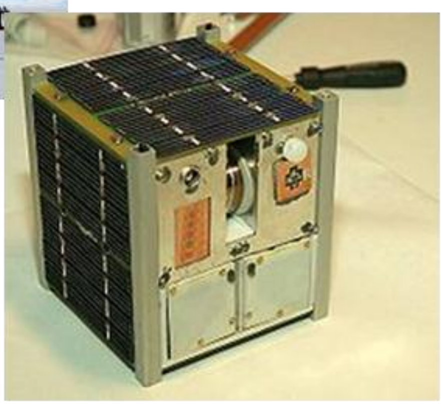
Military and Other Government Agencies

- **Soldier-Warfighter Operationally Responsive Deployer for Space (SWORDS)**
- **Unmanned Air Vehicles**
- **Robotic Vehicles**
- **National Oceanic and Atmospheric Administration (NOAA)**
- **National Science Foundation (NSF)**
- **Space and Missile Defense Command (SMDC)**

Credits: Photos taken from individual project presentations and websites

Academia, Business, and Community

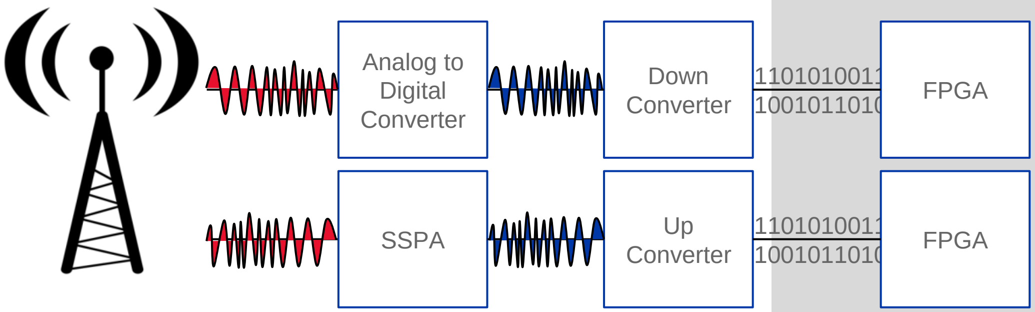
- **GATR – Portable Inflatable Satellite Dish**
- **University Launch Projects**
- **SmallSats and CubeSats**
- **Amateur Radio**
- **Amateur Rocketry**
- **Commercial Space**

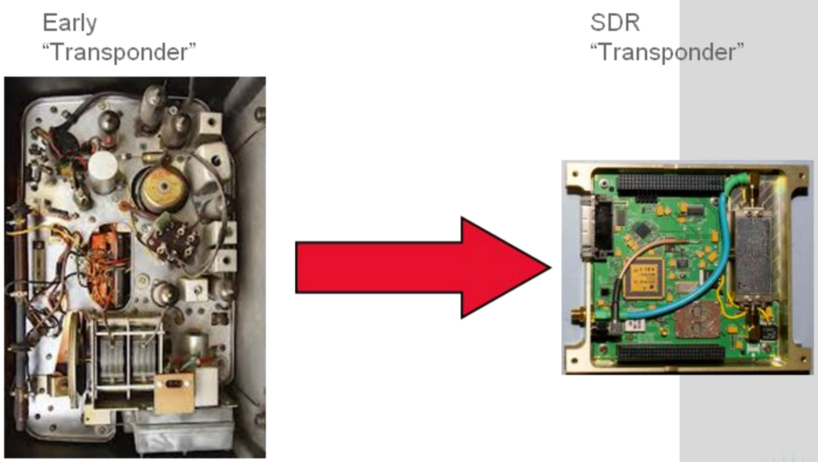


Credits: Photos taken from individual project presentations and websites

What is Software Defined Radio (SDR)?

- **SDR History**
  - Developed for Air Force in mid-1980's
  - Revolutionized by Digital Signal Processors in mid-1990's
  - Approved by FCC in mid-2000's
- **SDR Transponder**
  - Minimizes analog and radio frequency components
  - Digitizes signal for processing
  - Converts signals based on programmable logic





FCC – Federal Communications Commission
FPGA – Field Programmable Gate Array
SSPA – Solid State Power Amplifier

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