

## **Abstract**

This paper presents the tool chain, methodology, and initial results of a study to provide a thorough, objective, and quantitative analysis of the design alternatives for space Software Defined Radio (SDR) transceivers. The approach taken was to develop a set of models and tools for describing communications requirements, the algorithm resource requirements, the available hardware, and the alternative software architectures, and generate analysis data necessary to compare alternative designs. The Space Transceiver Analysis Tool (STAT) was developed to help users identify and select representative designs, calculate the analysis data, and perform a comparative analysis of the representative designs. The tool allows the design space to be searched quickly while permitting incremental refinement in regions of higher payoff.



# Modeling and Analysis of Space Based Transceivers



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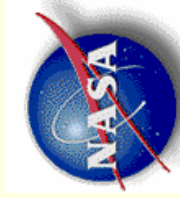
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# Overview

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- STRS project and its goals
- STRS Modeling and simulation approach
  - STRS Transceiver Analysis Tool (STAT)
- Example STRS models and analysis
- Interpretation of results
- Conclusions

# Space Telecommunications Radio System (STRS) Project

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- Examine the applicability of Software Defined Radio for space applications
- Identify (and quantify) the benefits and costs of various approaches
  - Fixed radio implementations
  - Reconfigurable SDR point solutions
  - Standard, open SDR architectures
    - JTRS SCA\*, or a space-specific standard?
- Develop an SDR architecture design for space

# Space Communications Systems

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- Unique space requirements
  - Radiation hard hardware devices (older HW technologies)
  - Size, Weight, & Power drive design very heavily
  - Not an economy of scale
    - Missions often have unique requirements → custom radios
    - Small numbers → argument for SW reuse is different
- Potential benefits of SDR for space
  - Develop later in project cycle (closer to launch time)
  - Re-program radios in flight (fix problems, evolve radios remotely)
  - Reduce the number of radios per mission (less sw&p)

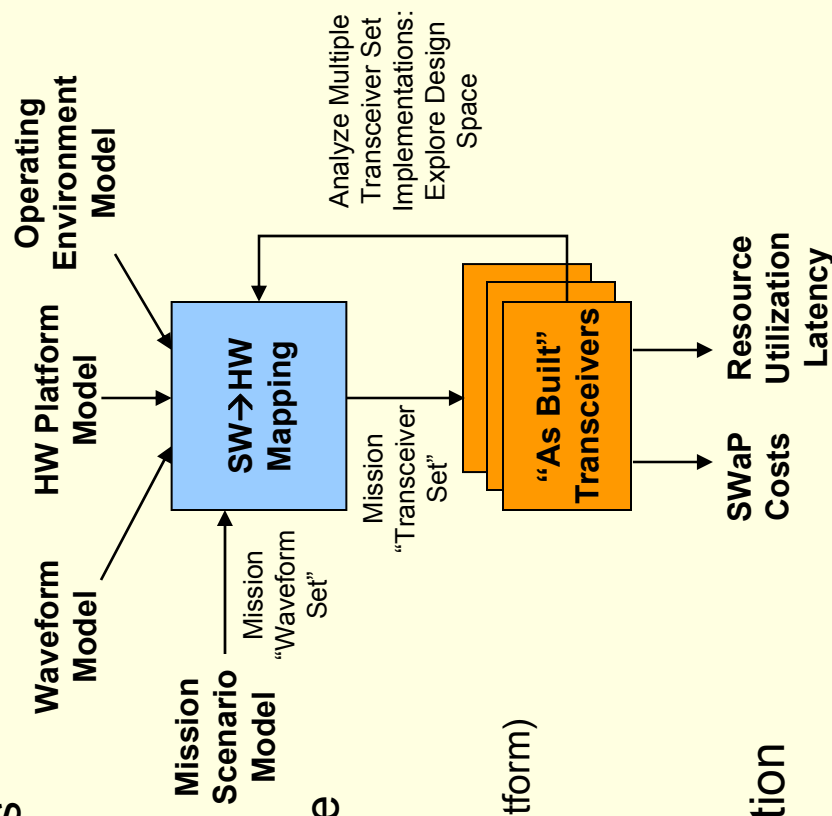
# STRS Modeling and Analysis Goals

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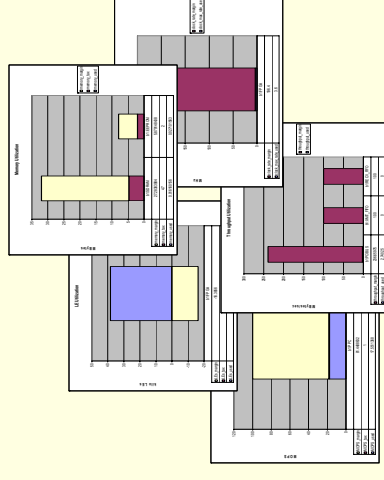
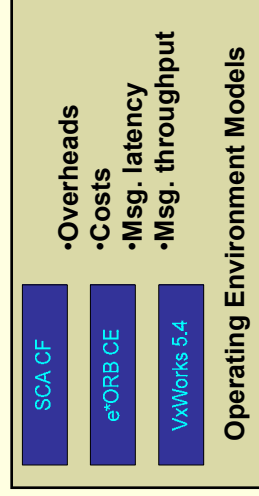
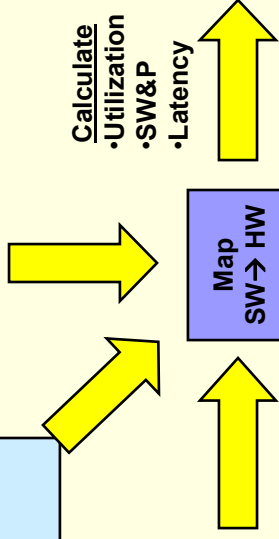
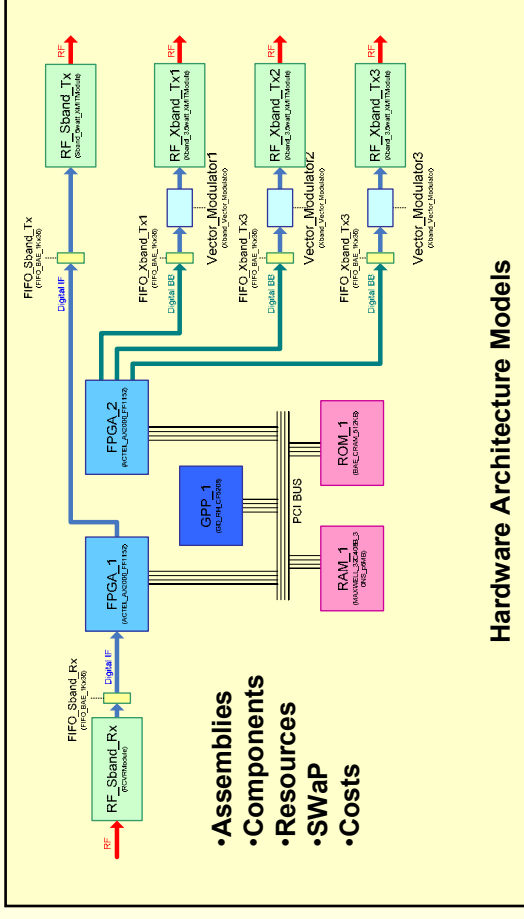
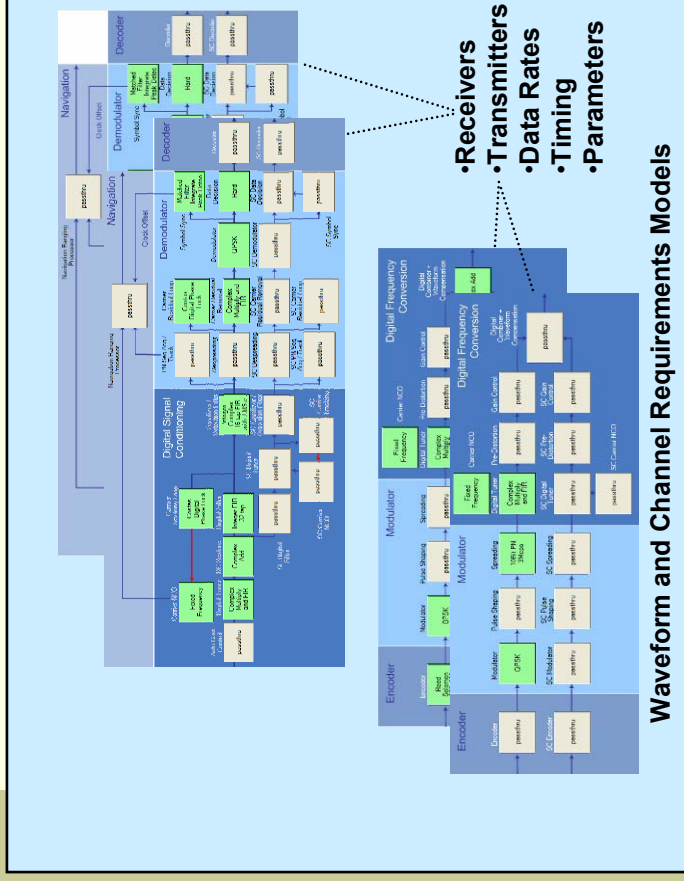
- Quantify the “costs” of reconfigurability (space-specific)
  - SW&P of resources required
  - Impact on modem latency
- Analyze SDR architecture options
  - Existing: JTRS SCA (existing implementations)
  - Notional: Custom space-specific architecture
- Examine the scalability of SDR architectures
  - Impact on both large and small missions
  - Low and high data-rates

# Space Transceiver Analysis Tool

- STAT developed for STRS project
  - Transceiver design-space analysis
  - Modeling in Excel and MATLAB
- Allows Modeling of
  - Mission channel requirements
  - Waveform algorithms and software
  - Hardware architectures
  - Software operating environments
  - Transceiver designs (waveforms→platform)
- Analyzes transceiver designs
  - Resource utilization
  - Size, weight, and power consumption
  - Modem latency



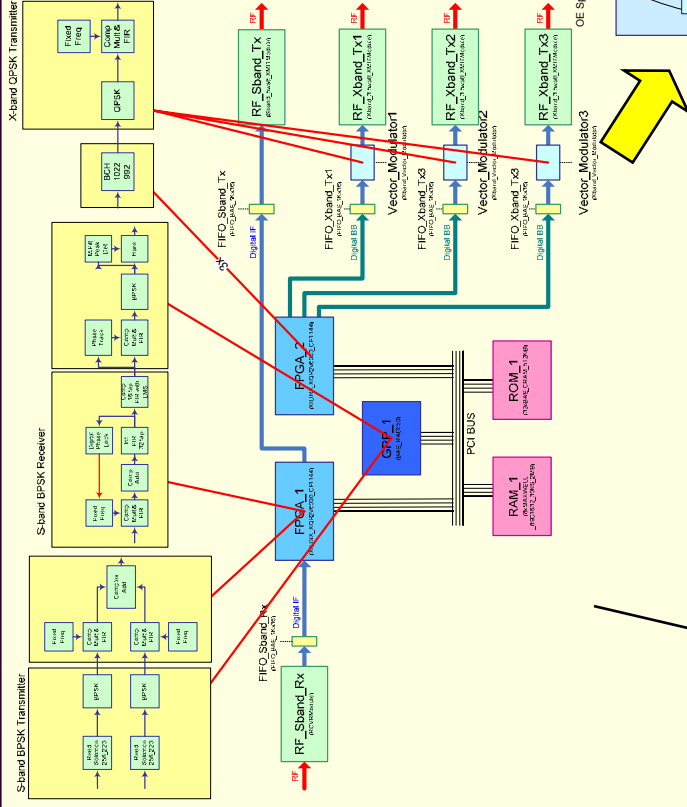
# STAT : Transceiver Design Space Analysis



**Analyze Trade Space**  
Adjust HW, OE, mapping  
Examine effect on costs



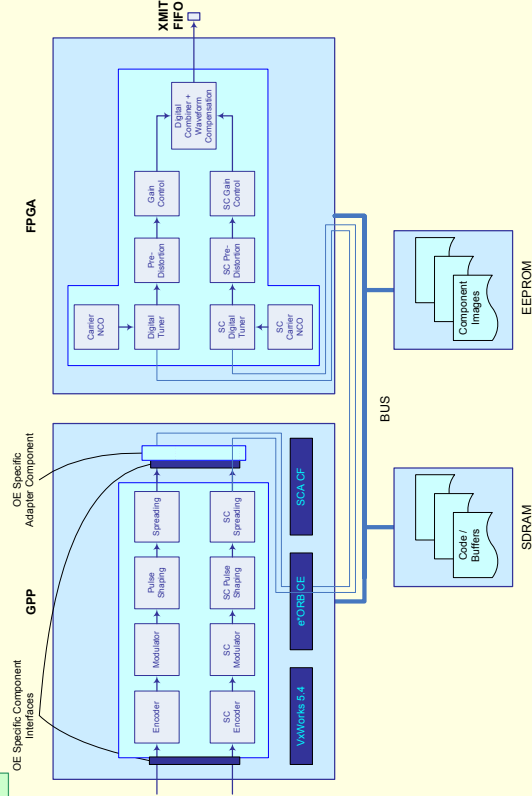
# Mapping Software → Hardware



Waveform to HW Mapping

“As Built” Transceiver Design

- Map SW → HW
- Produces “As-Built” transceiver
- Transceiver design can be analyzed
  - SWaP, development costs
  - Timing, resource utilization

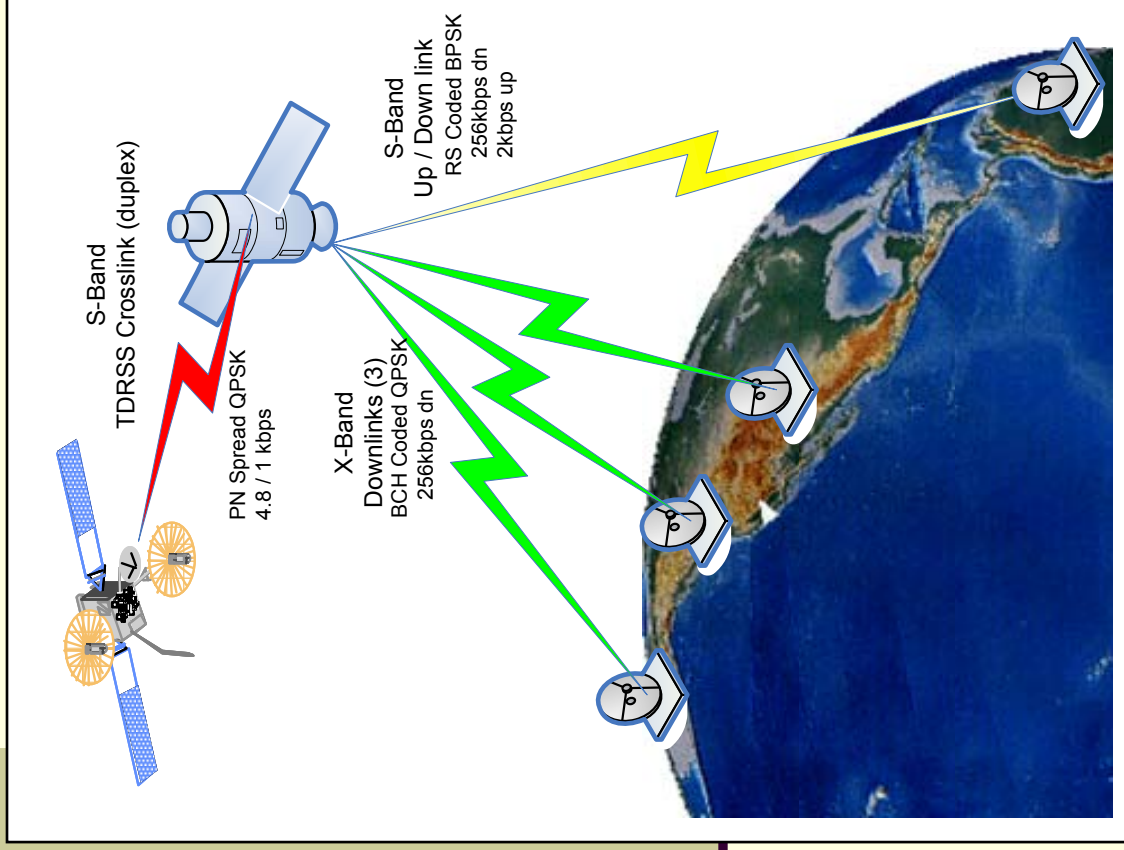


# Example : LANDSAT Mission Analysis

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- Provide objective answer to the question
  - “How much would using an open software architecture (such as JTRS SCA) for an earth observing mission effect the size, weight, and power consumption of the transceiver?”
- Model representative Earth observing mission (LANDSAT)
- Model LANDSAT waveforms (rates, resources, etc.)
- Model 3 implementation platforms / architectures
  - Fixed implementation (similar to legacy system)
  - Baseline reconfigurable implementation (minimal infrastructure)
  - LANDSAT SCA implementation (SCA infrastructure)
- Calculate SW&P for LANDSAT on each of these platforms

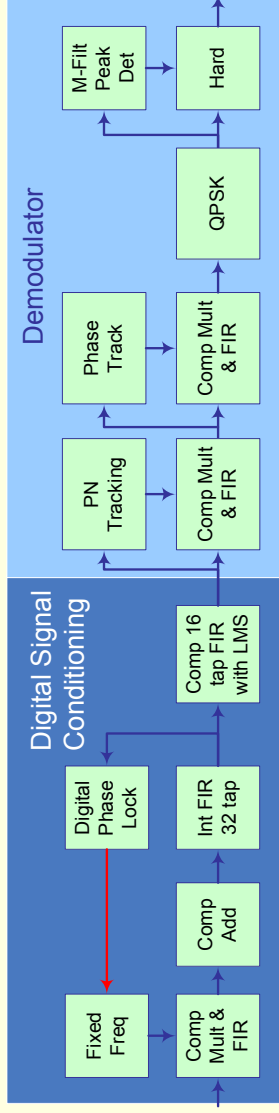
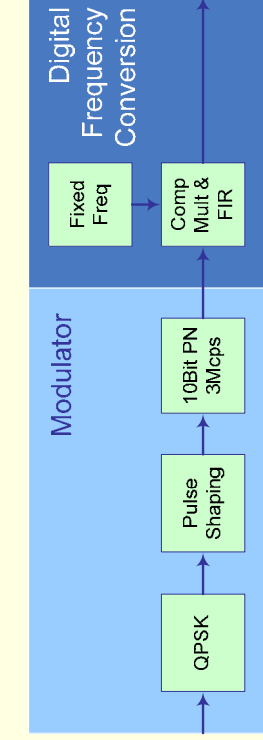
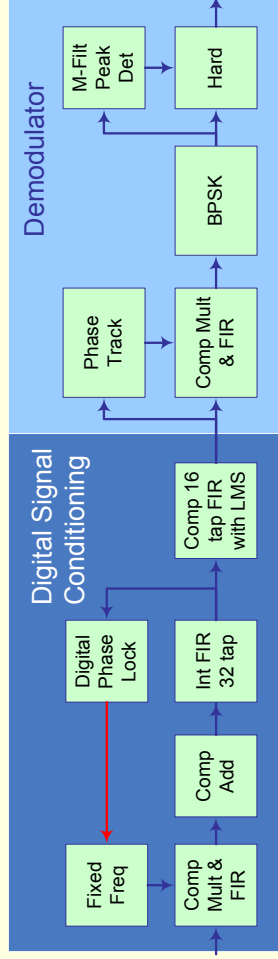
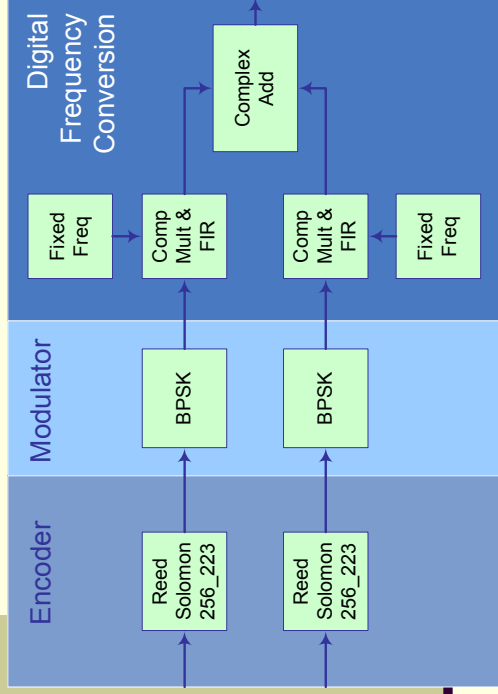
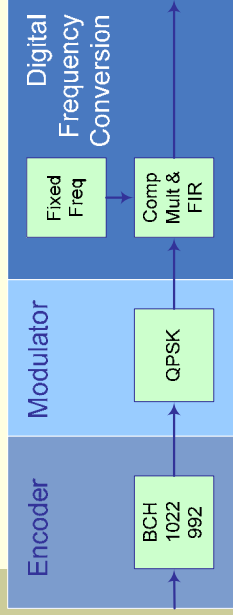
# LANDSAT Mission / Comm Links



- Channels
  - S-Band up/down link
  - 3 X-Band downlinks
  - S-Band crosslink
  - Waveforms (next slide)
  - Channel specs in models (rates, frequencies, etc)
- 2 Modes
  - Ground network
    - S-band command / TM
    - X-band science return
  - TDRSS crosslink

# LANDSAT Waveforms

- X-Band waveform
  - Dn: QPSK Tx
- S-Band waveforms
  - Dn/Up: BPSK Tx/Rx
  - TDRSS Crosslink: QPSK Tx/Rx

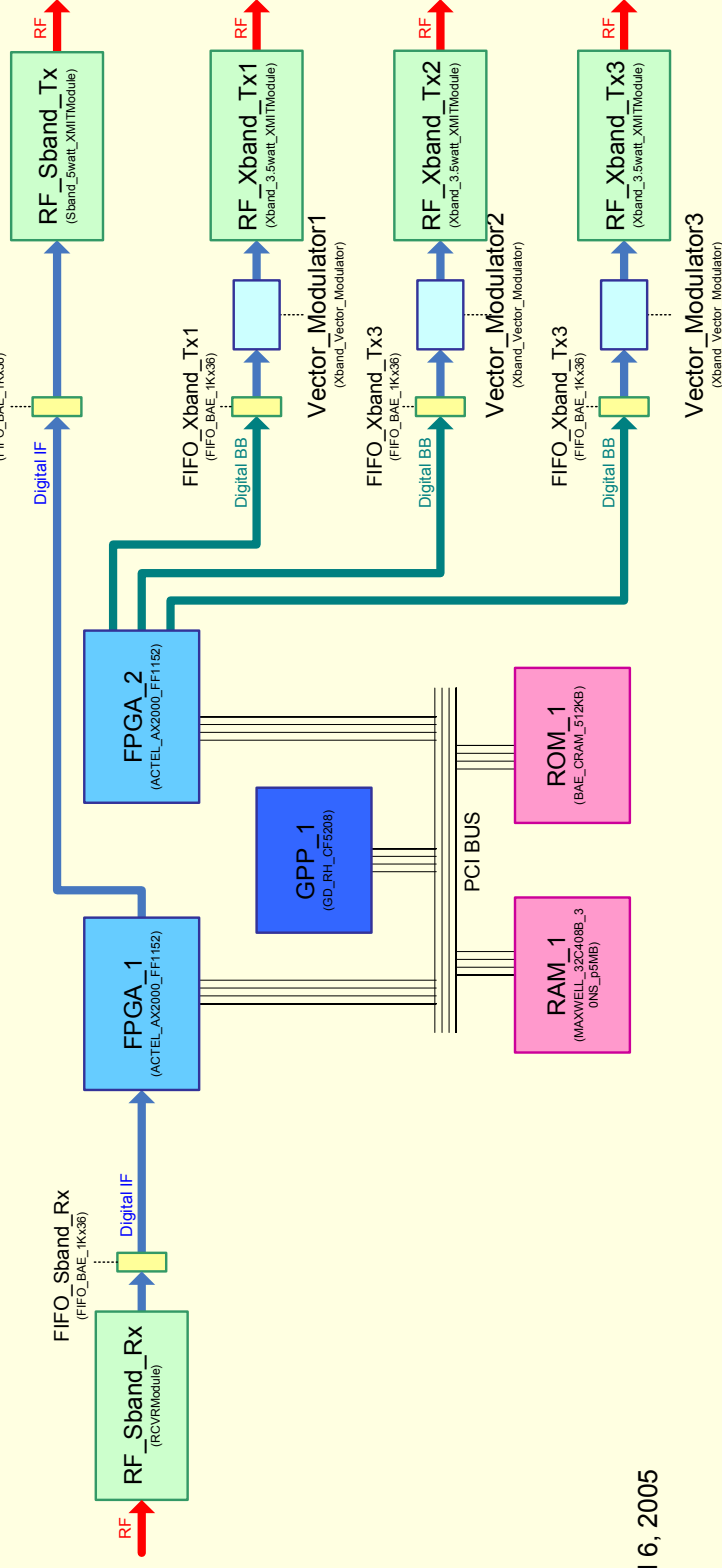


# LANDSAT Trade Study

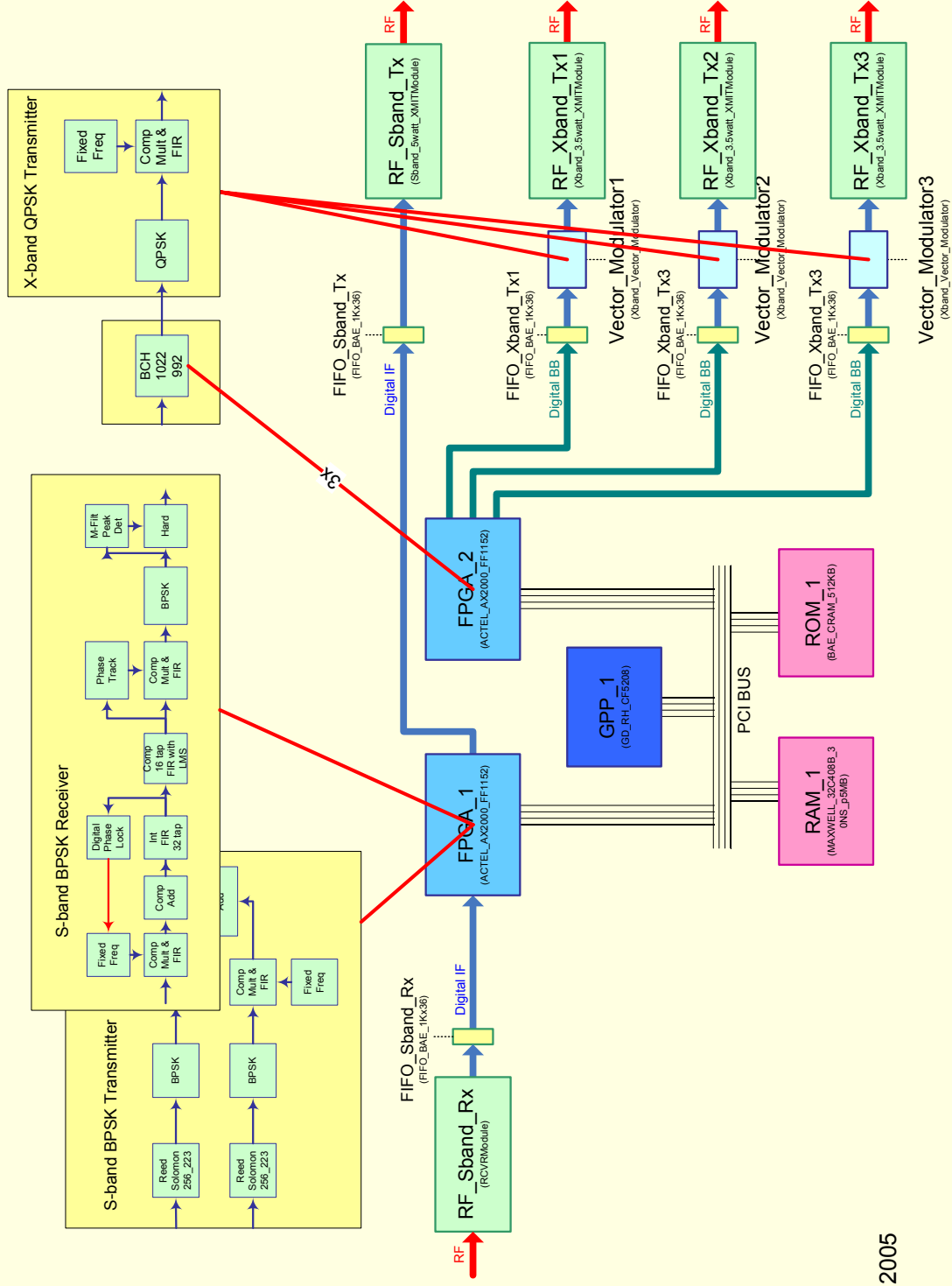
- Cost (SW&P) benefit analysis of LANDSAT SDR solutions
- Map LANDSAT waveforms to 3 classes of platforms
  - Fixed (*mostly* equivalent to legacy design)
    - Fuse-based FPGAs, minimal GPP and memory
  - Baseline Reconfigurable
    - Reprogrammable FPGAs, minimal GPP and memory
    - No CORBA or infrastructure
  - SCA Reconfigurable
    - Reprogrammable FPGAs, larger GPP and memory
    - SCA infrastructure
- For each – determine
  - Utilization (does the design meet requirements?)
  - Size, Weight, and Power (critical measures for space applications)

# LANDSAT : Fixed Platform

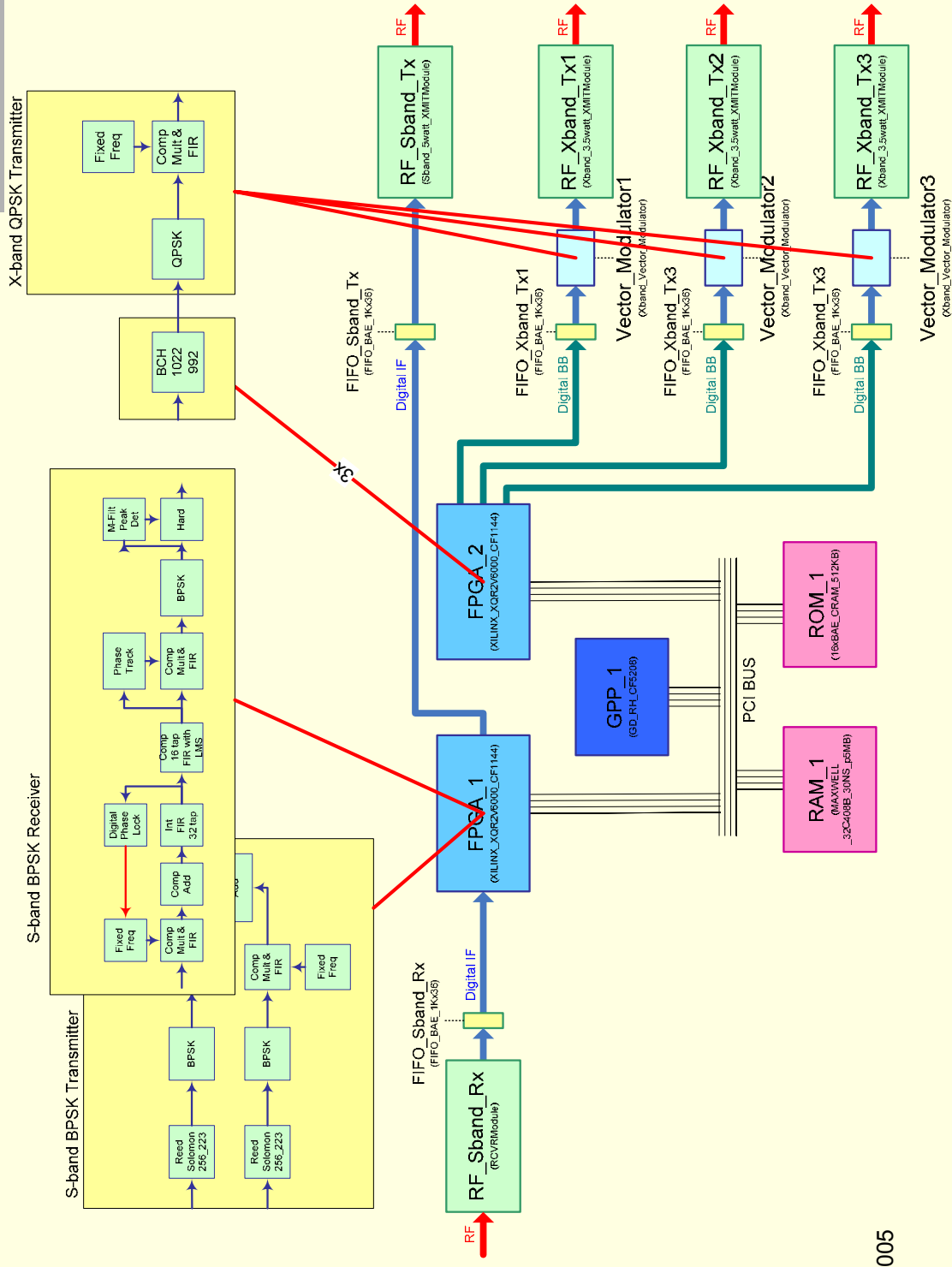
- 2 fuse-based FPGAs, a Cold Fire, RAM, ROM, cPCI bus
- S-Band RF Rx and Tx modules (LNA/PA, Filters, Rate Converters, etc)
- 3 X-band Vector Modulators and RF Tx modules (high rate modulation)
  - Analysis showed that the X-band IF rates >> FPGAs clocks
  - → Need vector modulators to support X-band rates



# LANDSAT : Fixed Platform Mapping



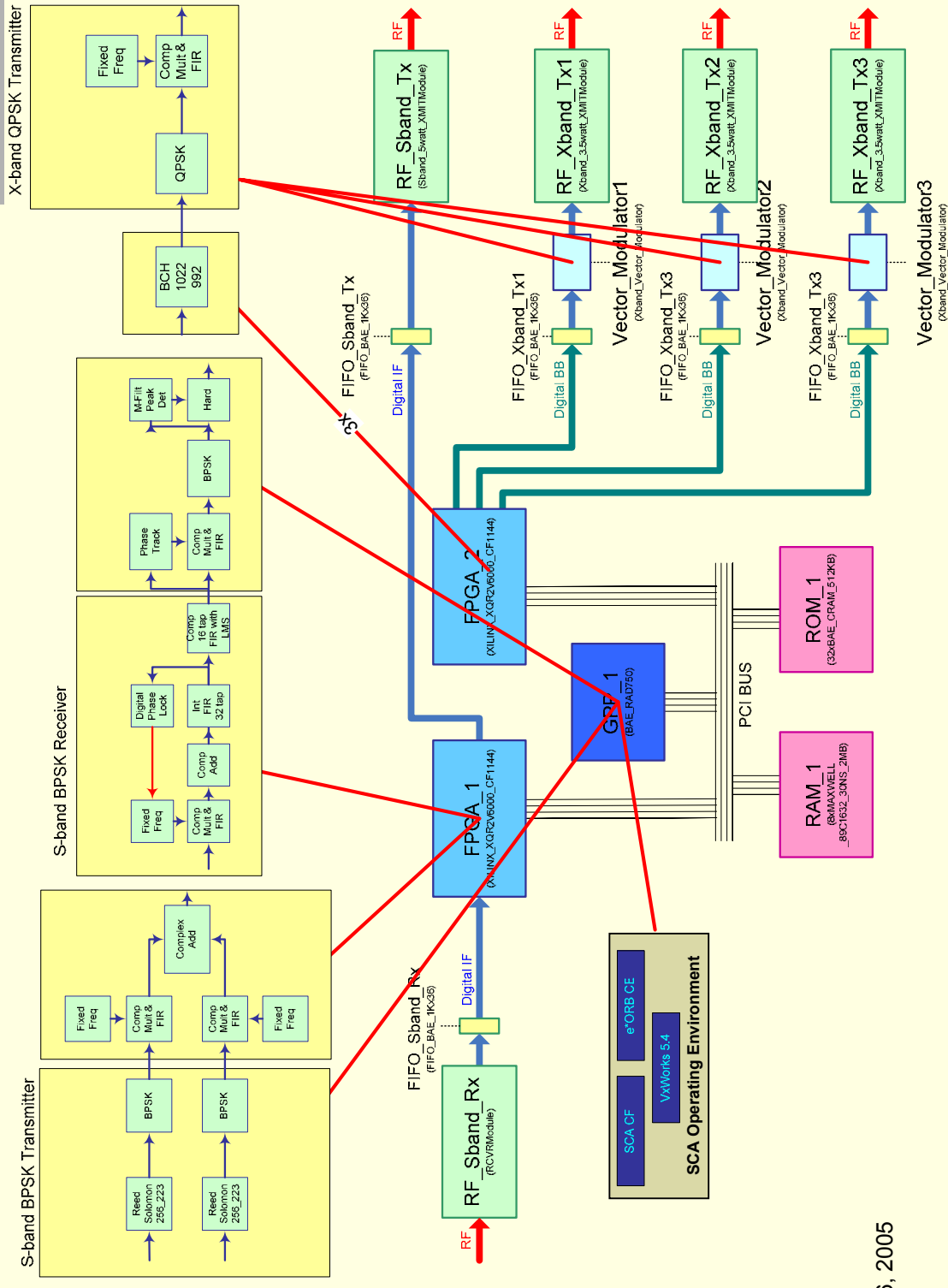
# LANDSAT : Baseline Reconfigurable Platform Mapping





# LANDSAT : SCA Reconfigurable Platform

## Mapping



# LANDSAT Trade Study Results

Transceiver	Size (in <sup>3</sup> )	Weight (lbs)	Power (watts)	Reconfigurability	Size %increase	Weight %increase	Power %increase
fixed	75.7	38.3	122.8	none	0.0%	0.0%	0.0%
reconfig_small	81.9	39.4	135.6	limited - custom format	8.3%	2.8%	10.4%
reconfig_large	94.6	41.5	170.2	full sca via xml	25.0%	8.4%	38.6%

- Initial analysis showed the need for vector modulators
  - The X-Band data-rates >> FPGA clock capabilities
- The RF components are identical in all 3 platforms modeled
- RF Tx/Rx modules dominate the weight and power
- Large portion of SW&P increase is due to large memory requirements of SCA core framework

# Conclusions

- STRS project → objective analysis to determine the applicability of SDR (and SDR architectures) to space
- The STAT tool was developed to provide modeling interfaces, and automated analysis, and it works
- Analysis on the LANDSAT mission scenario shows
  - Modem is not the dominant SW&P concern in the radio
  - SW&P for reconfigurability is potentially tolerable
  - Benefits of SCA to space are hard to quantify...
- Study has not complete, so the jury is still out

# Backup slides

# Novelty and Value of STAT Approach

- Quantify costs / benefits of
  - Utilizing reconfigurable SDR versus fixed hardware
  - Utilizing SCA (*versions*) versus different software architectures
- Modeling, Analysis, & Simulation trade studies
- Considered in the cost / benefit trades...
  - Required properties: scalability, flexibility, hw/sw independence, reconfigurability, portability, reliability
  - Impacts on performance: latency, throughput, functionality
  - Impacts on platform: size, weight, and power, memory, processing and communications capacity
  - Costs / benefits: development, maintenance and reuse costs, commonality in platforms, leverage of existing standards and infrastructures, # radios per mission

# Next Steps – Discussion

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- STAT relevance depends upon the quality of the models
- Validation is key, and will be done in two steps
  - Comparison of analysis vs. engineering rules of thumb
  - Comparison of modeled systems to real implementations
- Analyze other space missions
  - Include development costs
  - Arrive at a SDR architectural approach for space comms
- Integrate STAT into a design tool-chain
  - Bridge from SIMULINK®
    - Configure the transmitter / receiver dataflows
    - Calculate intermediate link rates more easily
  - Automated design space analysis

# STRS Modeling and Analysis Goals

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Objectively examine the tradeoffs involved in...

- Utilizing Software Defined Radio technology versus building fixed hardware (legacy) transceivers
- Adopting standard software architectures (e.g. SCA) versus build a custom software architecture

...and the impact of these choices on the...

- Size, weight, power, development cost
- Communications capabilities and performance

... of transceiver designs to support communications requirements of current and future space mission.