Test and Evaluation of Cognitive EA systems - Requirements for future test systems

KEYSIGHT TECHNOLOGIES

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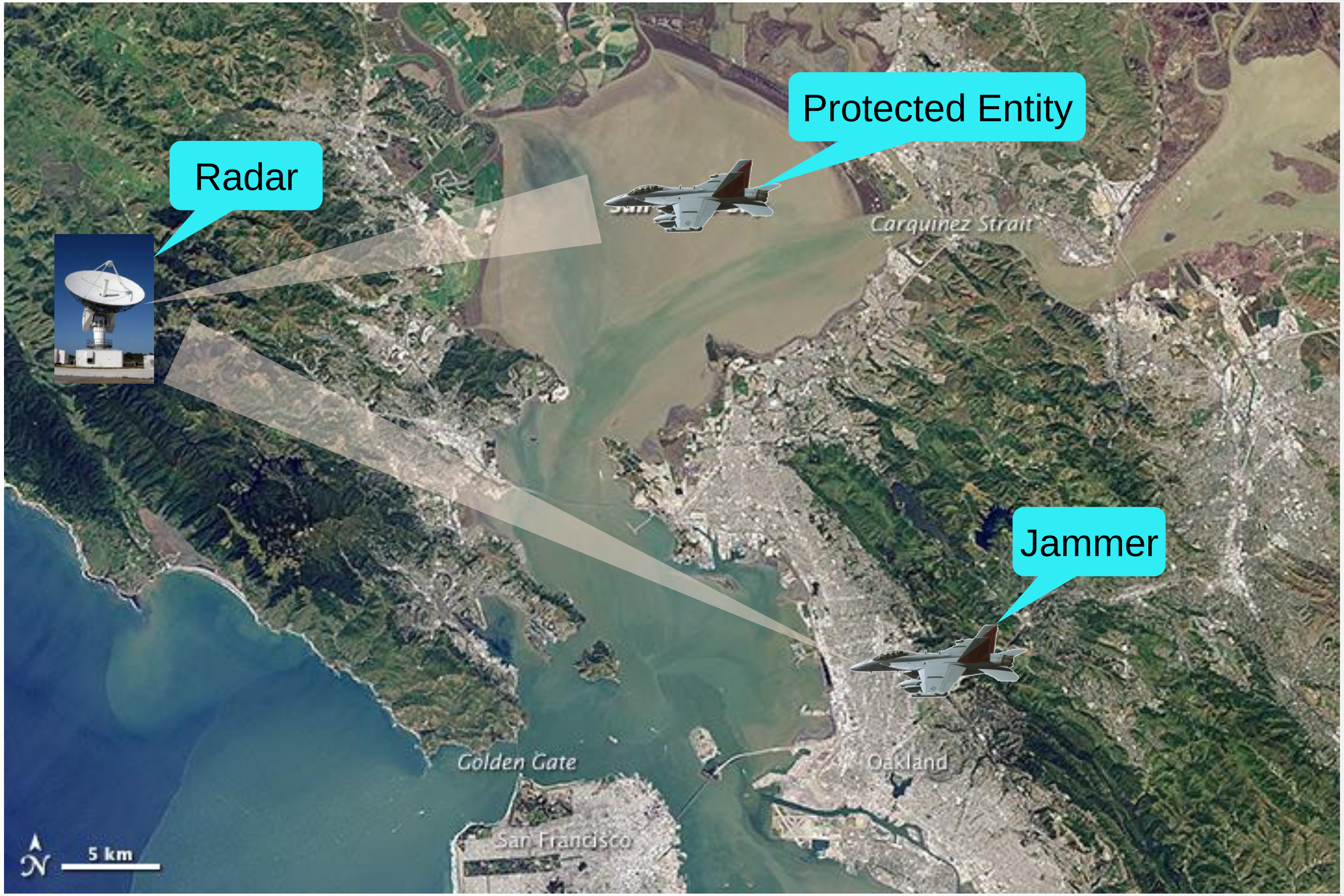
Situation

- You are designing and implementing cognitive electronic attack algorithms. How do you know that they will work in the field?
  - Computer simulations are a great start but sooner or later the algorithms must be tested in real hardware
  - Algorithms will need to be modified and improved many times, making flight range testing too expensive
- Need to test using hardware simulations of realistic conditions
- But… How do you test something if you don't know what it's going to do?
  - Cognitive algorithms mean the hardware will do whatever it wants - unpredictable
  - EA platform can maneuver autonomously
  - Need to emulate different kinds of radars, and they may be cognitive too
- How can you create an emulated environment?
- How can you tell if the EA algorithms are effective?

Simple Scenario

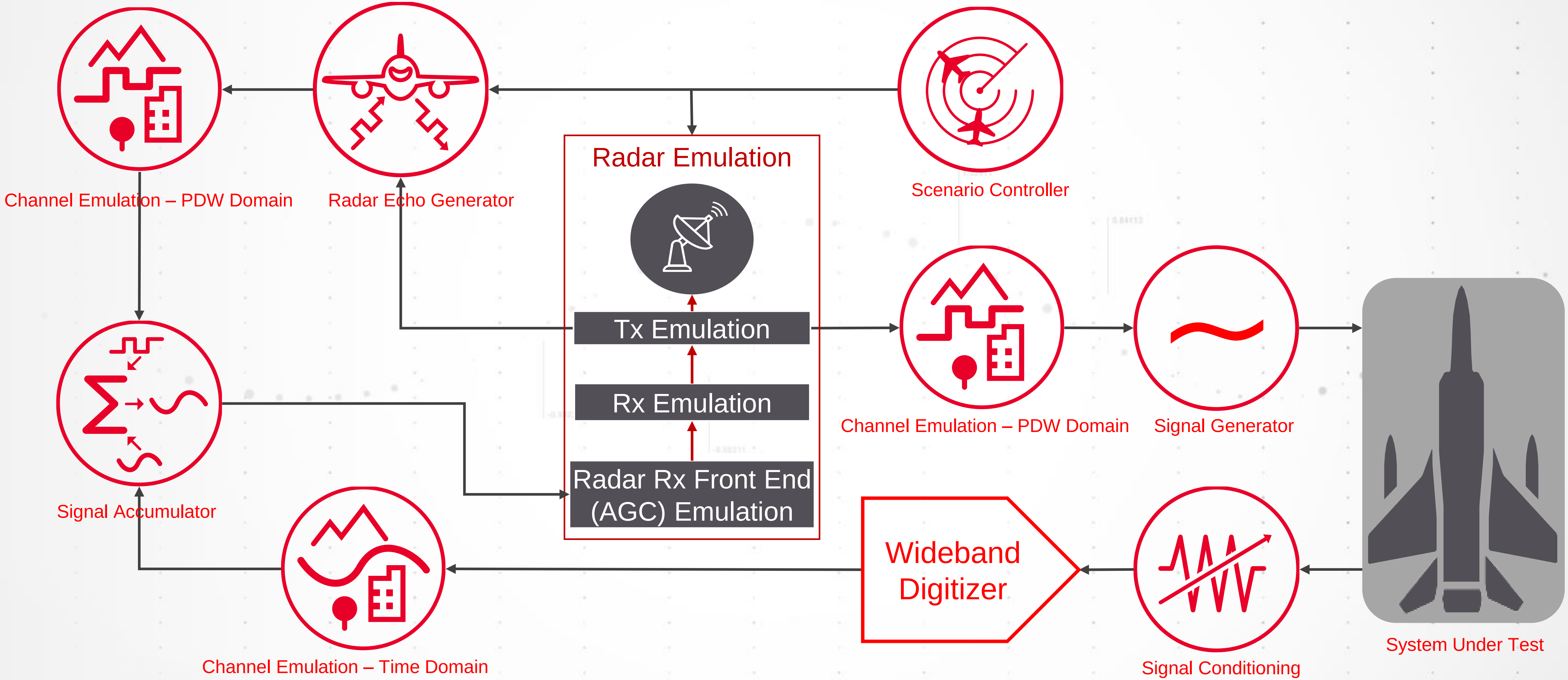
- Jammer is the SUT
- Everything else is emulated

- Scaling up to more complex scenarios to be considered later



Landsat imagery courtesy of NASA Goddard Space Flight Center and U.S. Geological Survey

Test System Block Diagram



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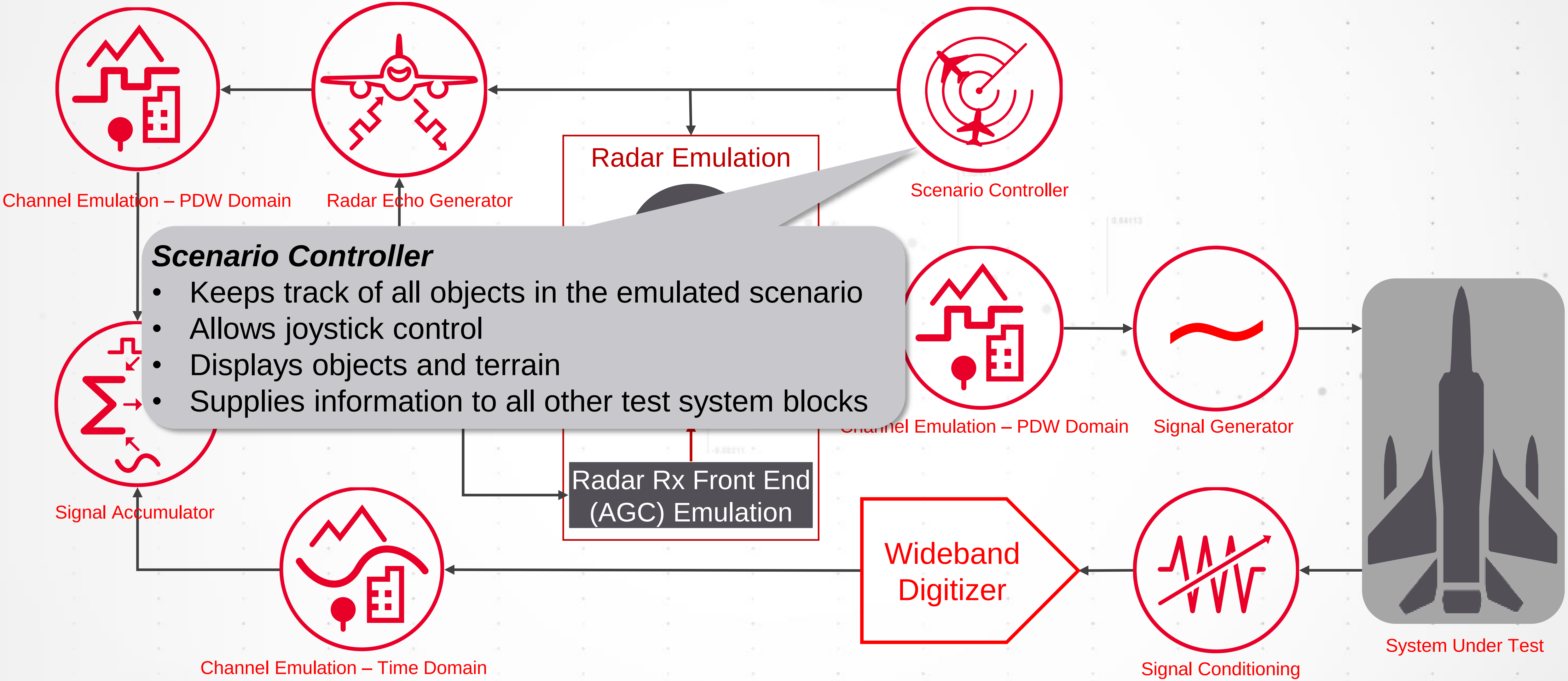


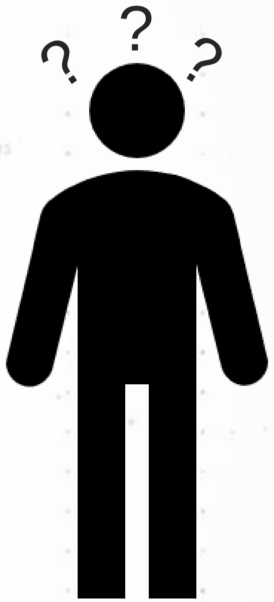
Scenario Controller

- Keeps track of all objects in the emulated scenario
- Allows joystick control
- Displays objects and terrain
- Supplies information to all other test system blocks

Challenges

SCENARIO CONTROLLER

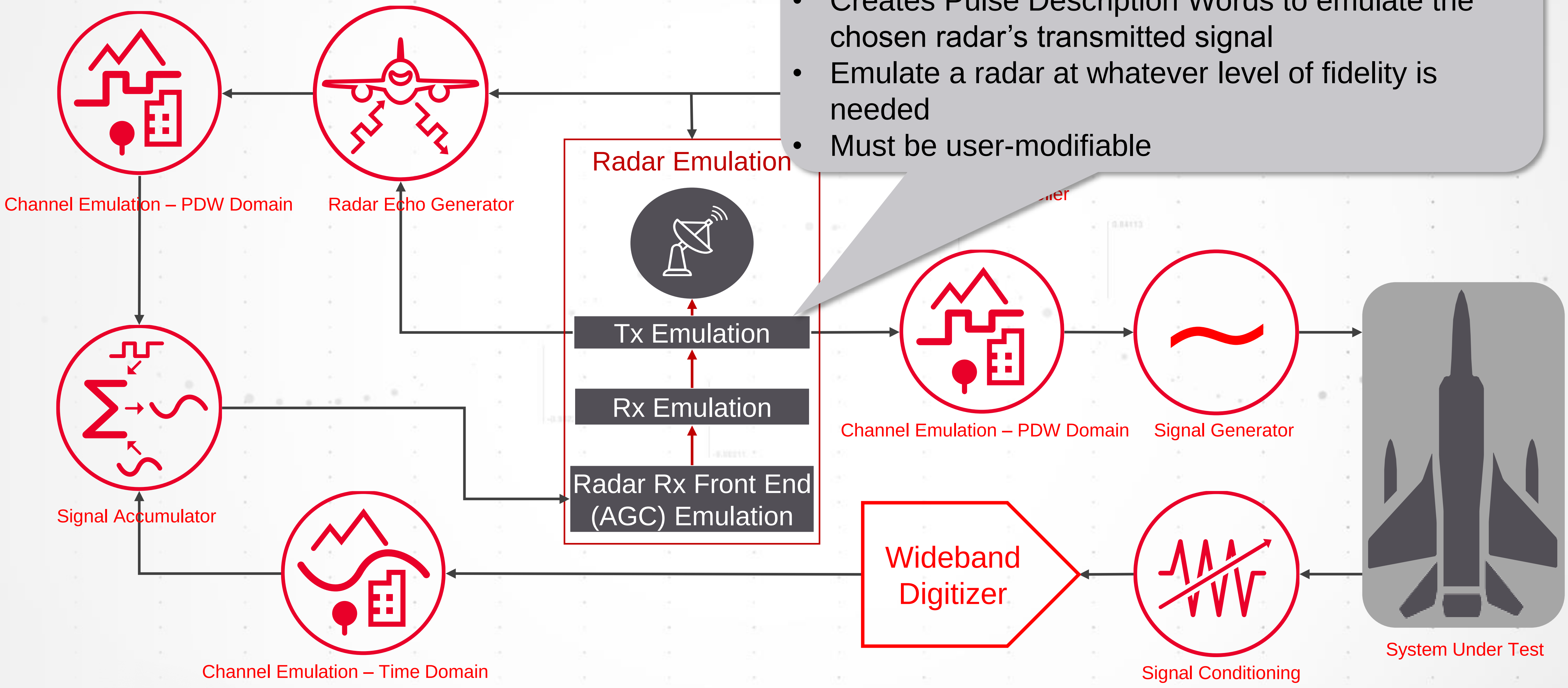
- SUT may function and maneuver autonomously
  - Need a two-way communication path between the SUT and the scenario controller
    - Scenario controller needs to know where the SUT is at any given time
    - SUT needs to know if it is about to crash into a mountain
- Timing is key – precise timing between all system elements is critical
- This scenario controller is not the same as the available COTS radar environment emulators.
  - Architected for closed-loop operation
  - Must have a high-speed interface that allows other test system blocks to obtain necessary data



Test System Block Diagram

Radar Transmitter Emulator

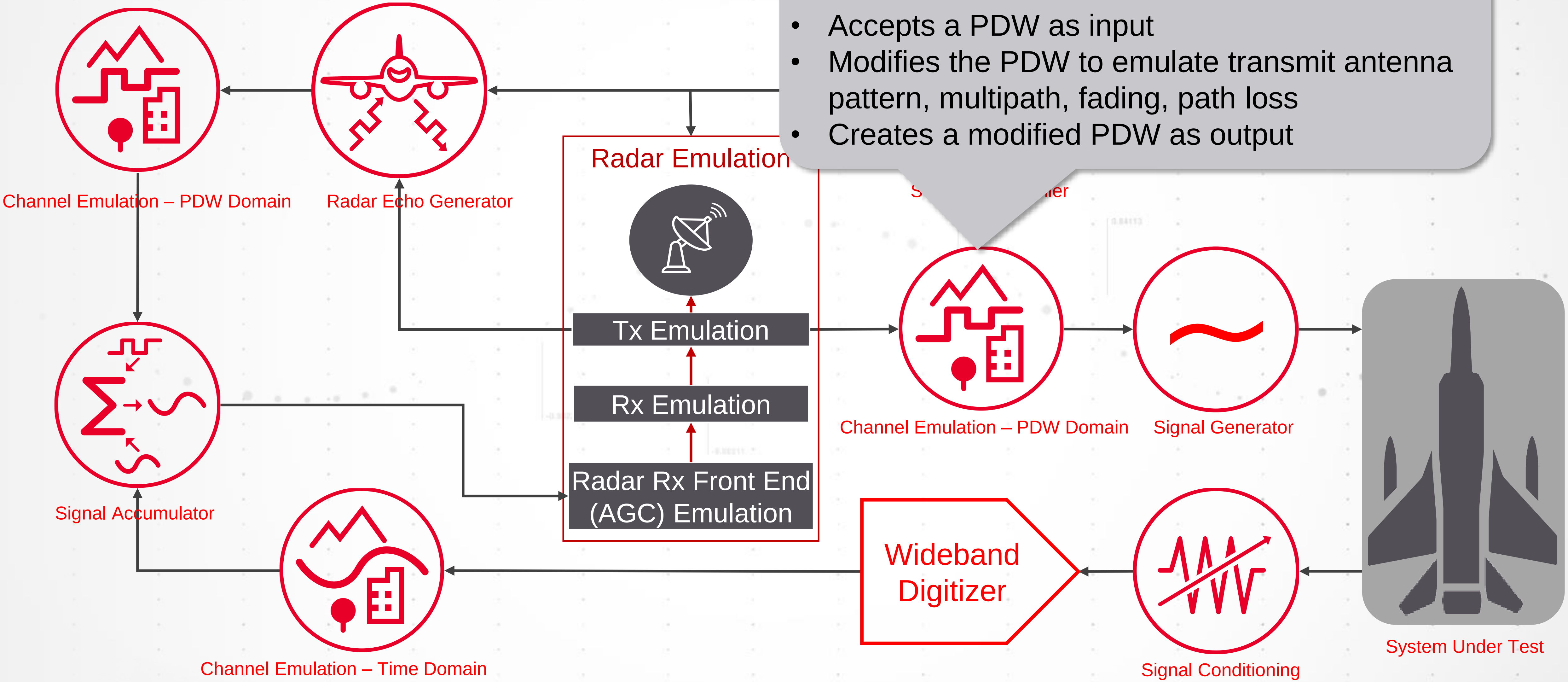
- Creates Pulse Description Words to emulate the chosen radar's transmitted signal
- Emulate a radar at whatever level of fidelity is needed
- Must be user-modifiable



Test System Block Diagram

Transmitter Channel Emulation

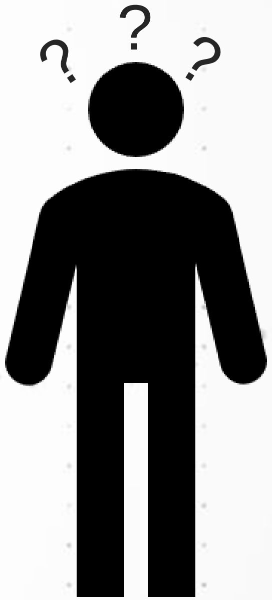
- Accepts a PDW as input
- Modifies the PDW to emulate transmit antenna pattern, multipath, fading, path loss
- Creates a modified PDW as output



Challenges

TRANSMITTER CHANNEL EMULATOR

- Test system knows the beam direction of the radar but not the beam direction of the SUT
  - Need a communication path between the SUT and the transmit channel emulator in order to properly scale the SUT's input signal
- SUT antenna might be an array
  - Use many sources, or a beamforming network? Expensive
  - Insert transmitter signal behind the antenna? Need a physical connection point
- SUT might be trying to execute direction-finding algorithm using an antenna array
  - Expand the system to use many sources?
    - Requires a calibration step
    - Makes the system more expensive
  - Communicate with the SUT to 'push' the correct direction into the SUT's memory?
    - Requires special test mode and software communication with the SUT



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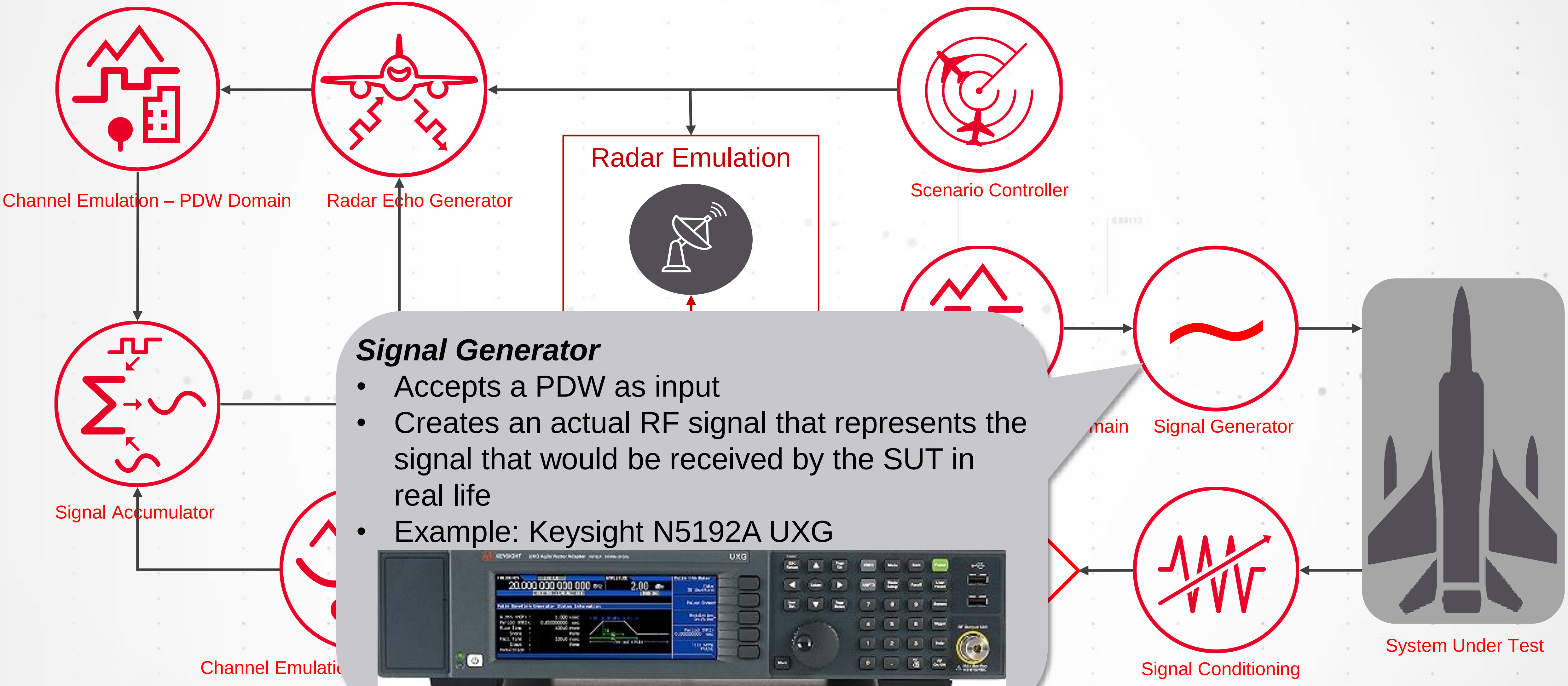
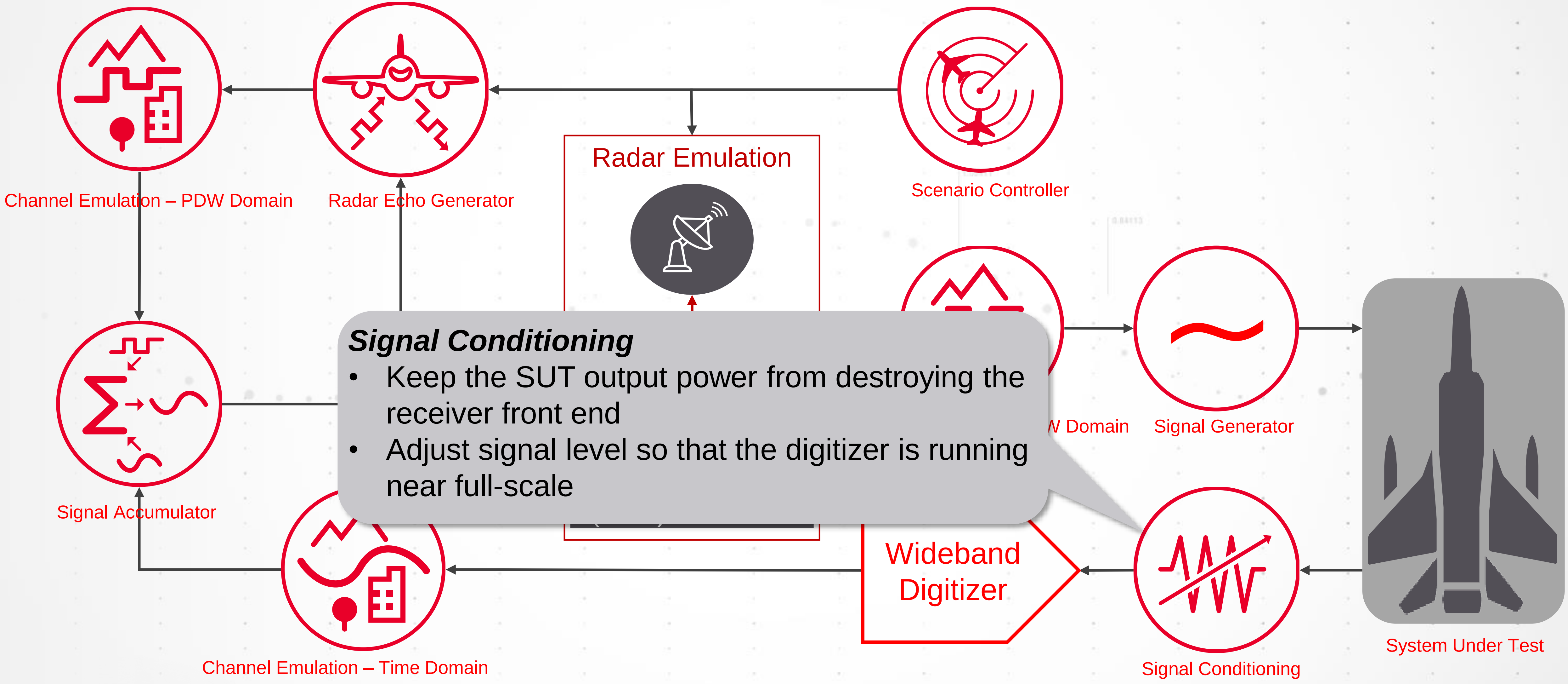


Signal Generator

- Accepts a PDW as input
- Creates an actual RF signal that represents the signal that would be received by the SUT in real life
- Example: Keysight N5192A UXG

Test System Block Diagram



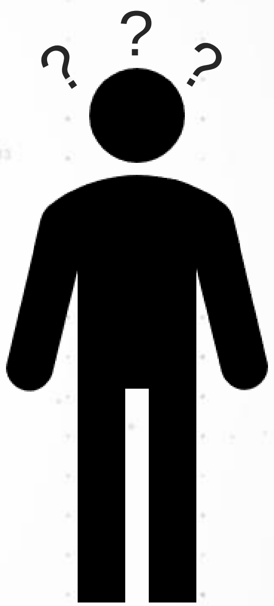
Signal Conditioning

- Keep the SUT output power from destroying the receiver front end
- Adjust signal level so that the digitizer is running near full-scale

Challenges

SIGNAL CONDITIONING

- SUT output power many change rapidly at any time
  - Too-high power will damage the test system
  - Too-low power will result in loss of digitizer dynamic range
- Need SUT communication to predict power changes in advance
  - Need fast switching
- Or, implement very fast signal conditioning with power sensing
- Signal conditioning attenuation factor must be transmitted to other downstream test system blocks
  - Otherwise, radar emulator will think it always sees a high power signal



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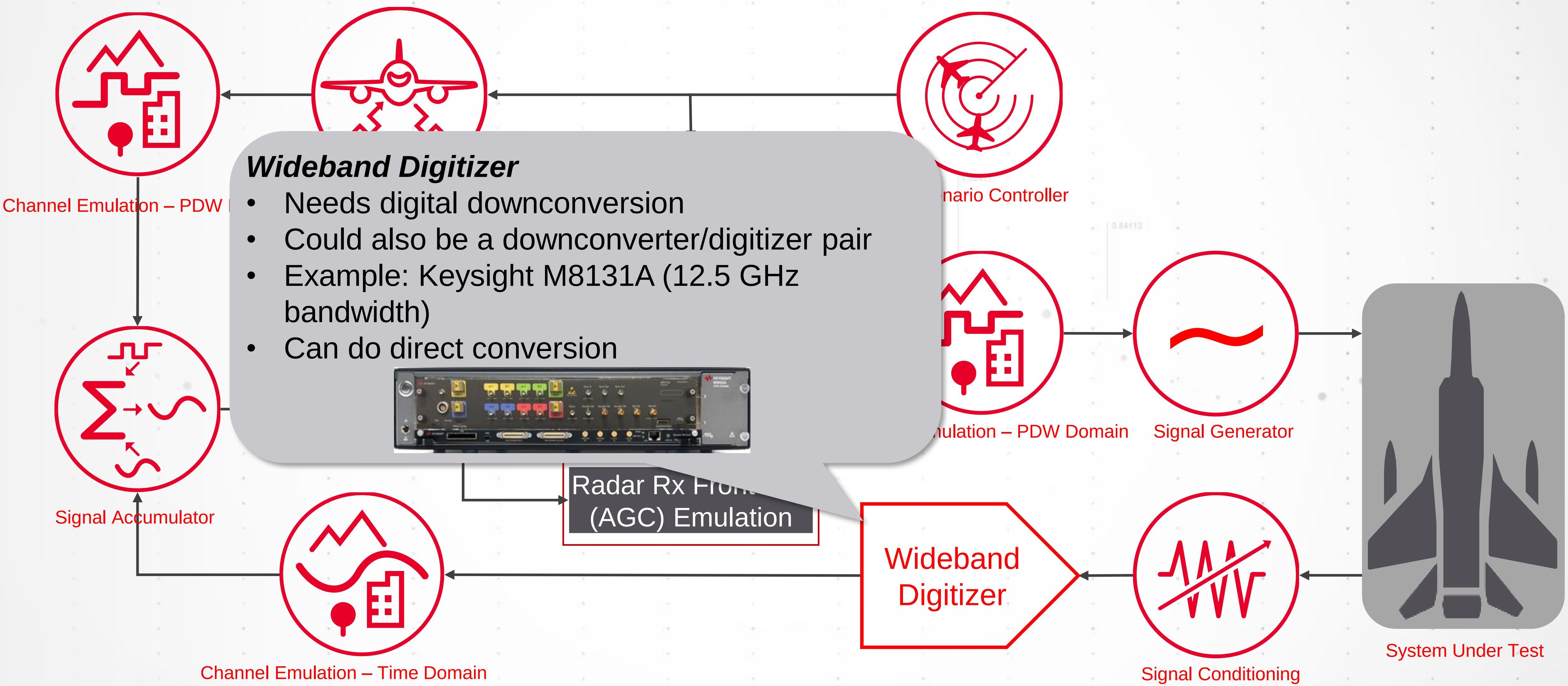
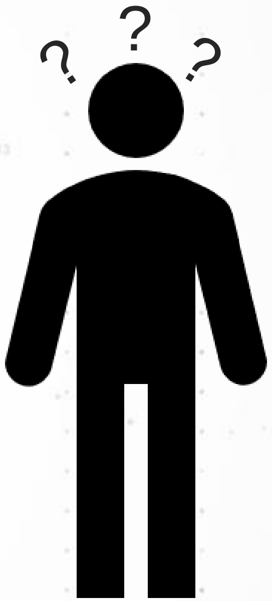


Challenge

DIGITIZER/RECEIVER

- SUT Signal may frequency-hop
  - Need to know the signal frequency to properly tune the receiver
- Need communication with SUT to tune properly
- Or, capture wide bandwidth and seek/select signals in DSP
- Or, query radar transmitter for the current frequency and assume the SUT will match that
  - Will not work if there is more than one radar in the scenario



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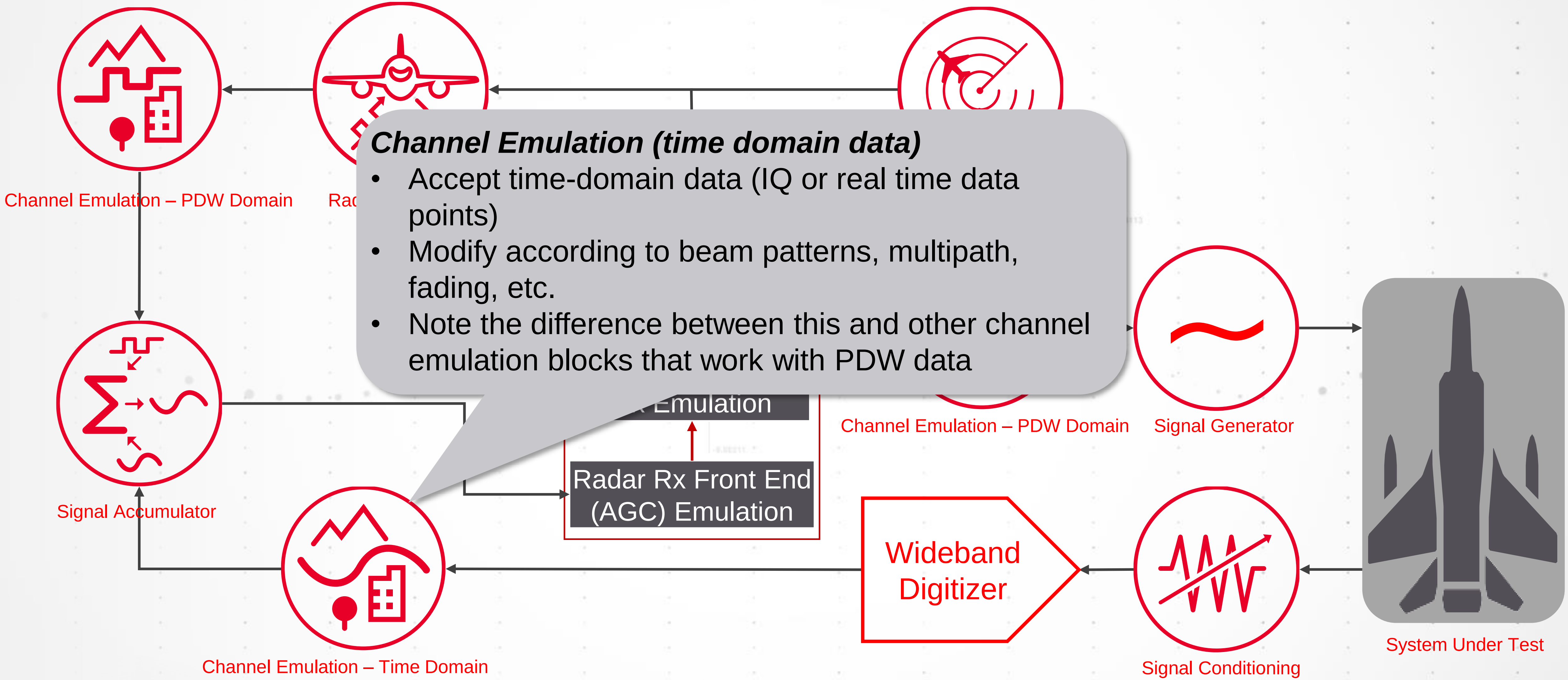
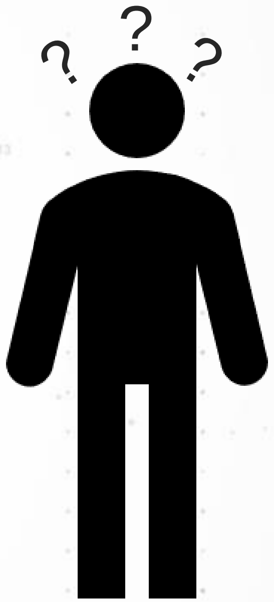


Challenges

RECEIVED SIGNAL CHANNEL EMULATION

- Test system does not know the beam-pointing direction of the SUT's transmit antenna
  - Required in order to correctly scale the received signal
  - Need communication with the SUT
- Channel emulation is computationally expensive
  - SUT may transmit any waveform, not necessarily just pulses
    - Channel emulator must work in time domain, not PDW domain
  - Available COTS channel emulators have sufficient bandwidth
    - …but usually take RF input, not digital, and only work up to 6 GHz or so



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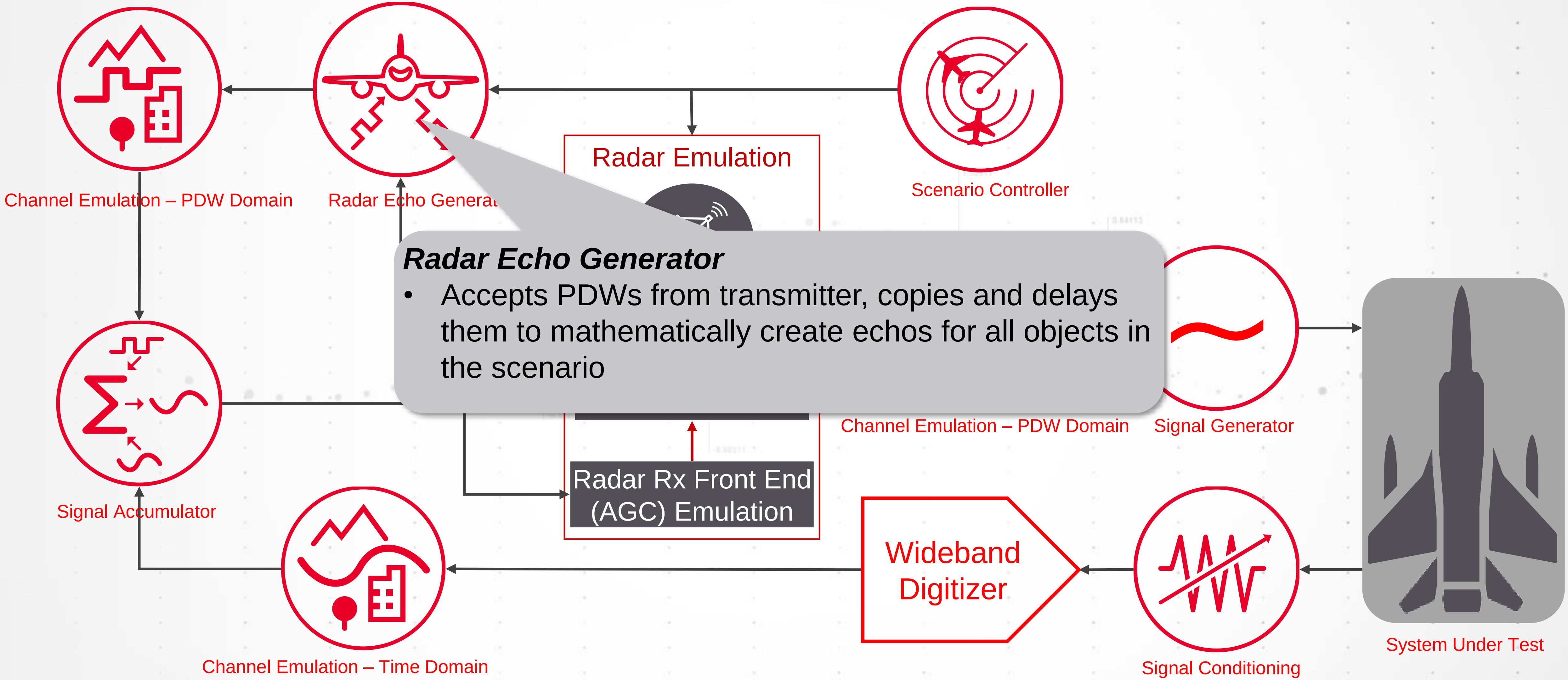
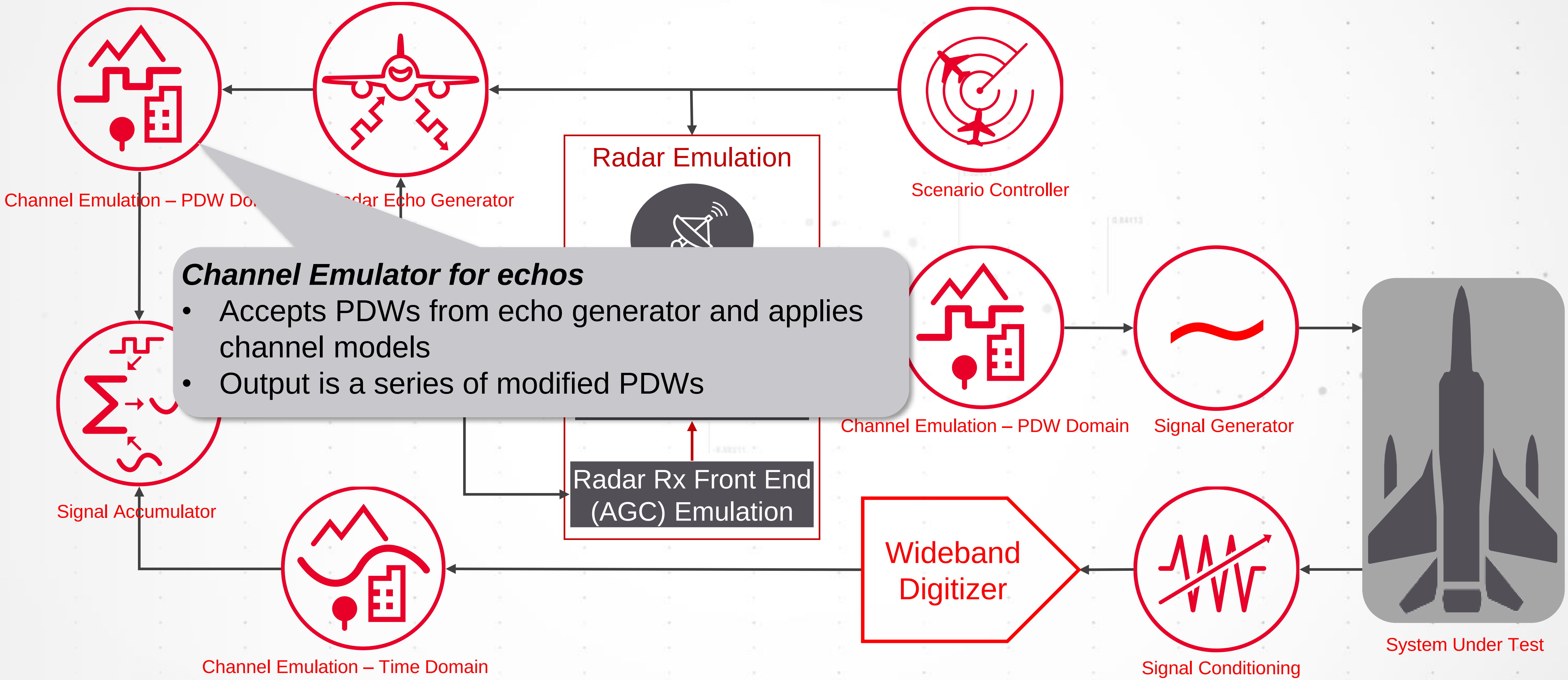


Radar Echo Generator

- Accepts PDWs from transmitter, copies and delays them to mathematically create echos for all objects in the scenario

Test System Block Diagram



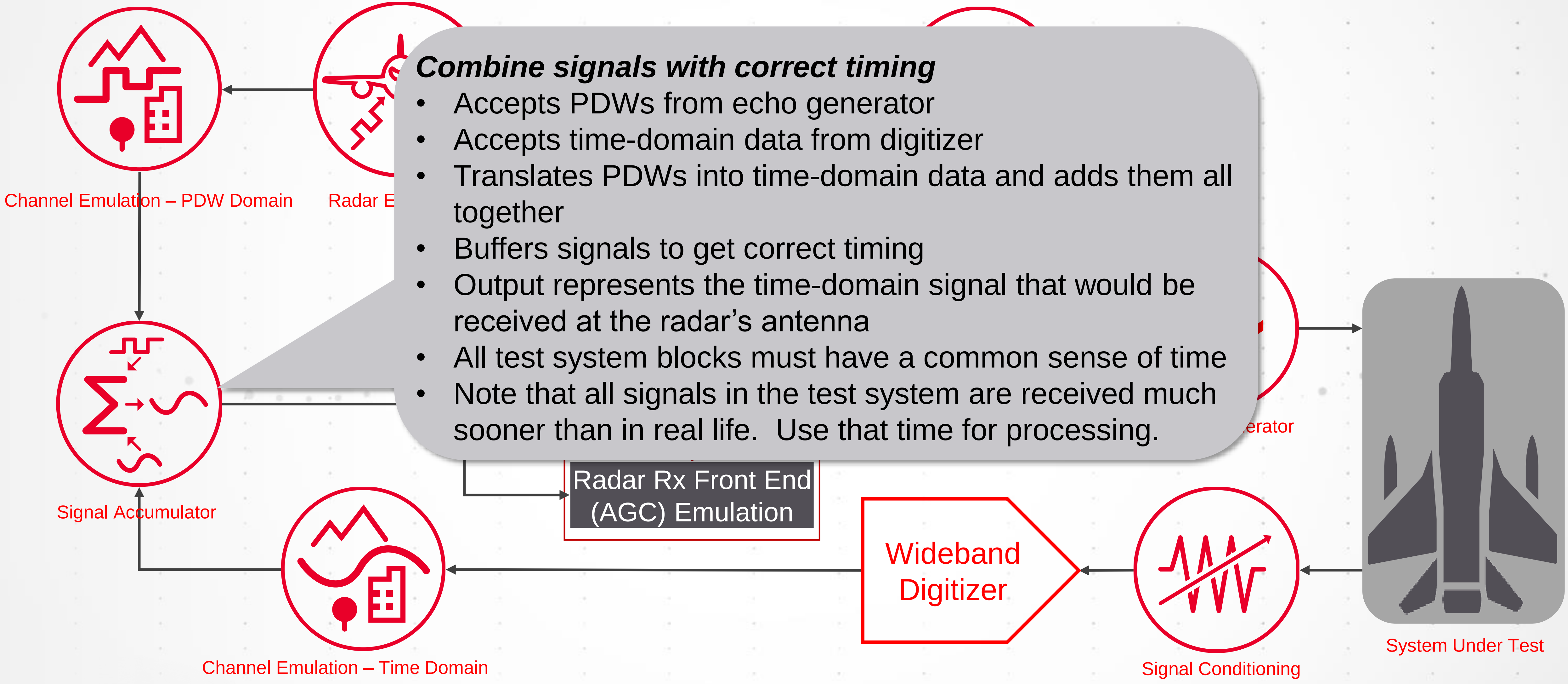
Channel Emulator for echos

- Accepts PDWs from echo generator and applies channel models
- Output is a series of modified PDWs

Test System Block Diagram

Combine signals with correct timing

- Accepts PDWs from echo generator
- Accepts time-domain data from digitizer
- Translates PDWs into time-domain data and adds them all together
- Buffers signals to get correct timing
- Output represents the time-domain signal that would be received at the radar's antenna
- All test system blocks must have a common sense of time
- Note that all signals in the test system are received much sooner than in real life. Use that time for processing.



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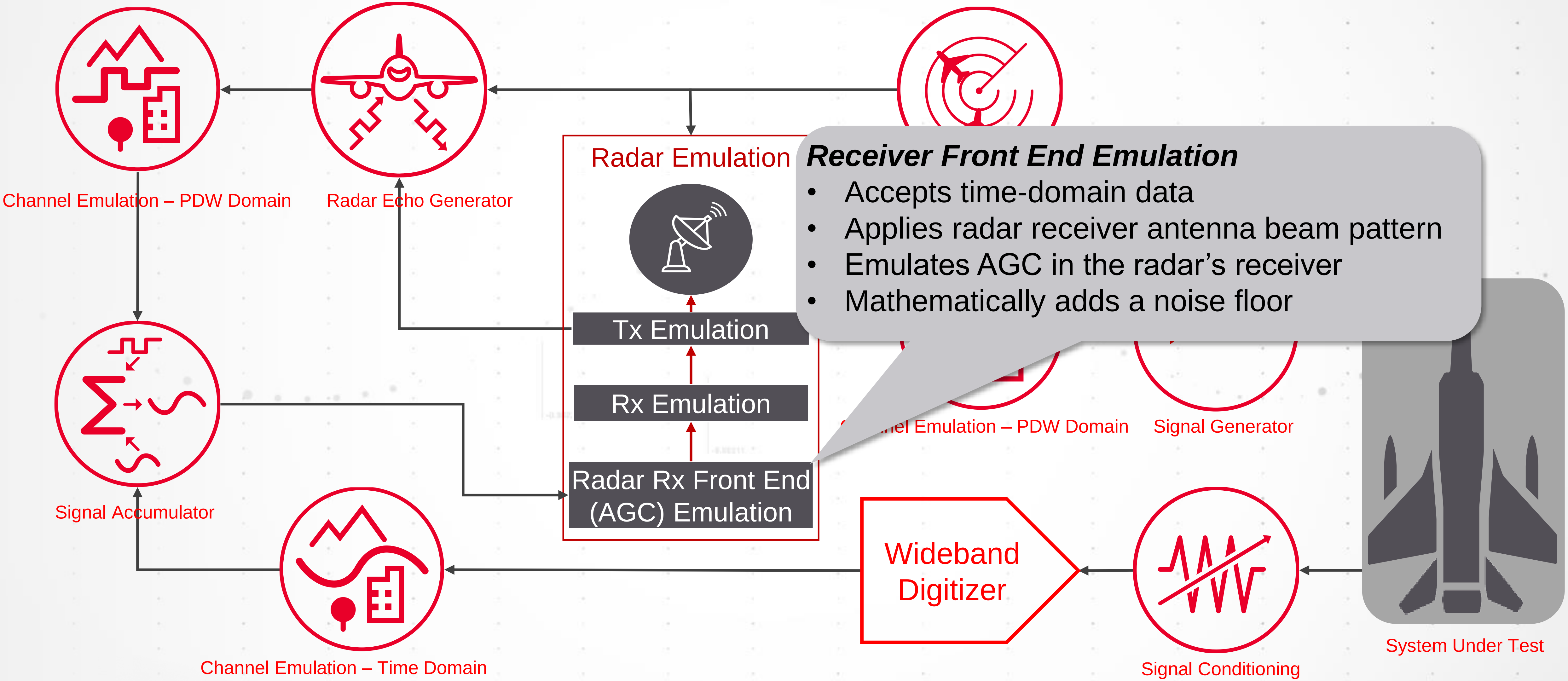
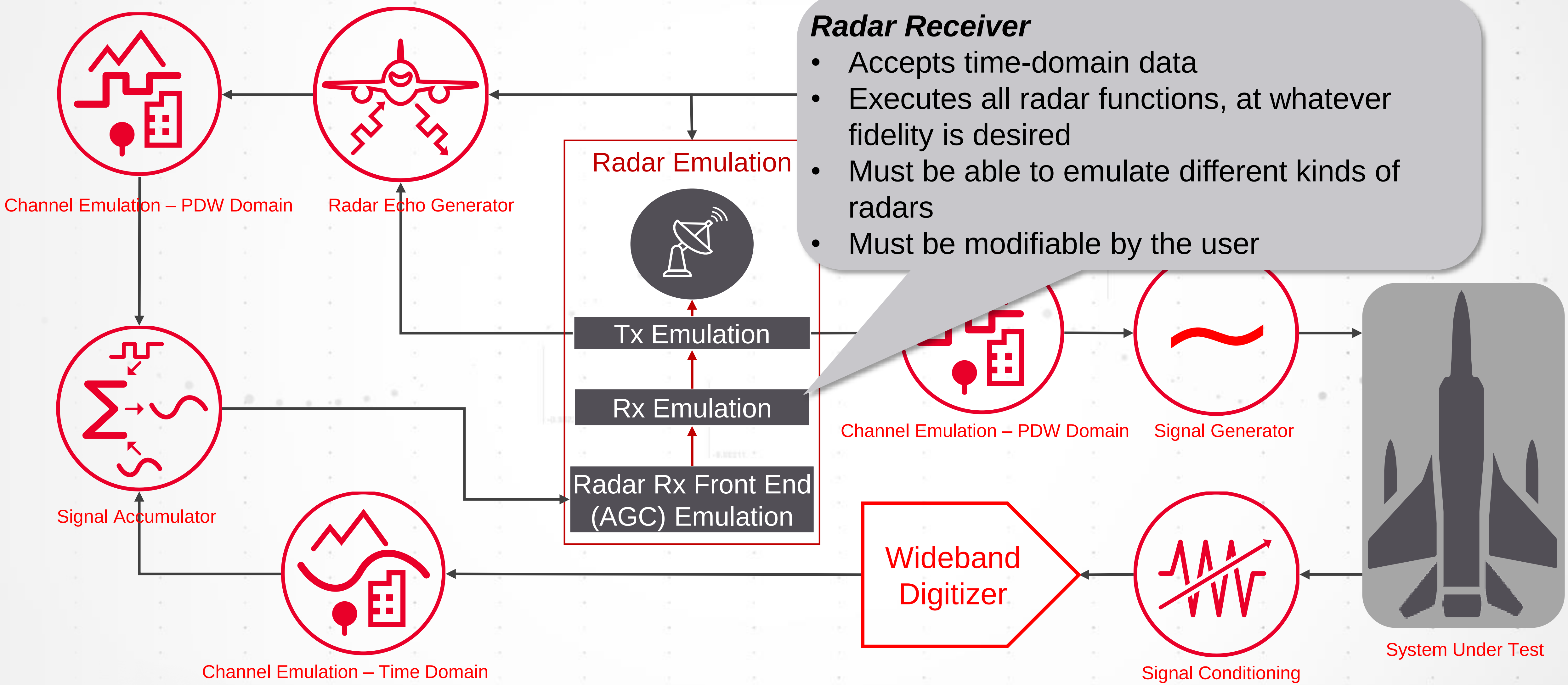


Receiver Front End Emulation

- Accepts time-domain data
- Applies radar receiver antenna beam pattern
- Emulates AGC in the radar's receiver
- Mathematically adds a noise floor

Test System Block Diagram



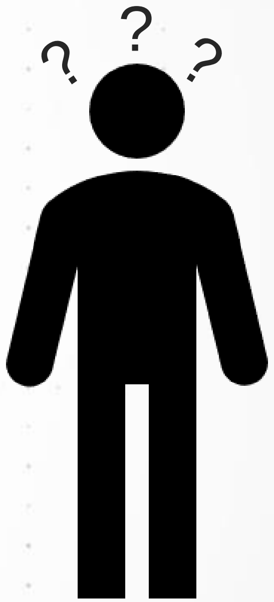
Radar Receiver

- Accepts time-domain data
- Executes all radar functions, at whatever fidelity is desired
- Must be able to emulate different kinds of radars
- Must be modifiable by the user

Challenges

RADAR RECEIVER

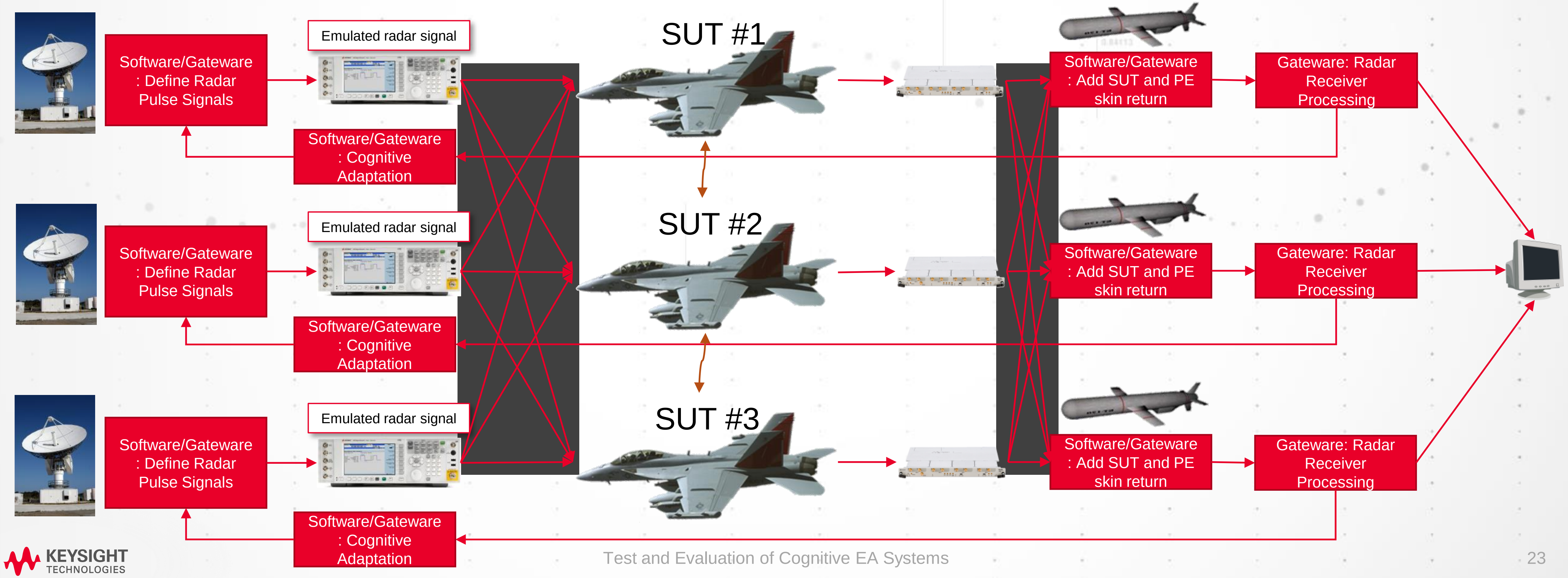
- Radar receiver algorithms must be modifiable by the user
  - Implies a library of FPGA-based IP that can be easily modified to implement different types of radars
  - Requires an application-specific tool that can be used to accomplish changes easily
    - Keysight PathWave:FPGA one example of such a tool
    - Still requires significant expertise on the part of the user
- There is no standard way to measure the SUT's effect
  - Success may be mission-dependent
    - Did the SUT successfully fool the radar for long enough?
    - Did the radar operator discover too quickly that the system was being attacked?
    - Was the radar able to get a fire-control solution on its target before the mission was complete?
  - Best current solution: Record all signals and carefully analyze later
    - Better test system would have real-time displays to ensure that everything is working
  - Industry would benefit from a standard, consistent measurement for EA effectiveness



Scalability

OBVIOUS SOLUTION IS CLUMSY

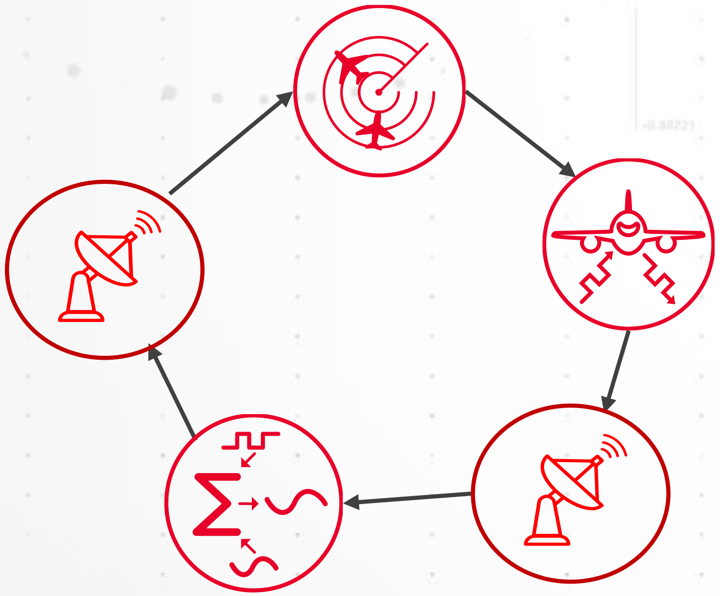
- Brute-force test system design is not scalable
  - Signal routing paths increase factorially with the number of objects in the scenario



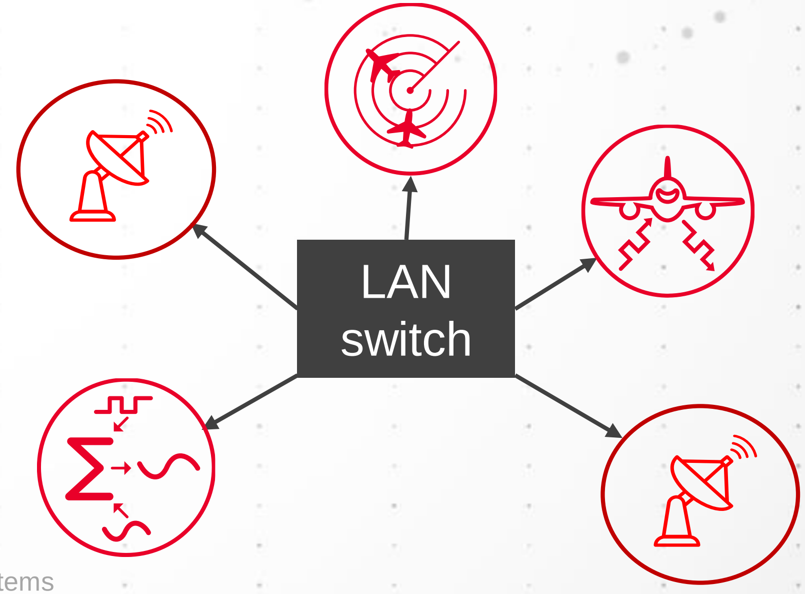
Scalability Solution? (But needs further investigation)

NOVEL TEST SYSTEM ARCHITECTURE POSSIBILITIES

- **Ring Architecture**
- All test system blocks form a ring network
- All data flows around the ring at high speed
- Test system blocks store the data they need, then forward everything to the next block



- **Star Architecture**
- Star configuration on a high-speed network
- All test system blocks broadcast relevant data to all other blocks
- Receiving blocks store the data they need, ignore the rest



Summary

THIS PROBLEM CAN BE SOLVED BUT NOT EASILY

- Cognitive EA system tests must be close-loop
  - Completely different architecture from common radar environment generators
- Significant communication with the SUT is strongly desired
  - Standard interface would be very welcome
- Measures of EA effectiveness have not been standardized
  - Industry-wide standard would be welcome
- Scalability is an issue
  - Requires new kinds of thinking regarding test system architecture
- **Call To Action**
  - The same kind of innovation needed in new operational systems (EA, comms, etc.) is also required for systems that test them
  - When architecting a new system, these things must be considered

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