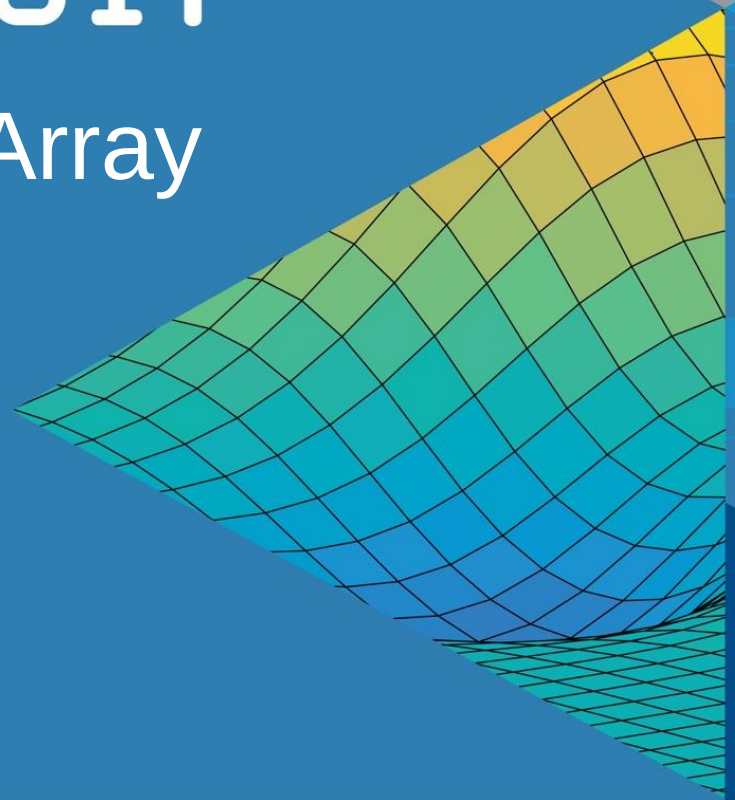
MATLAB EXPO 2017

System Design for Phased Array Radars

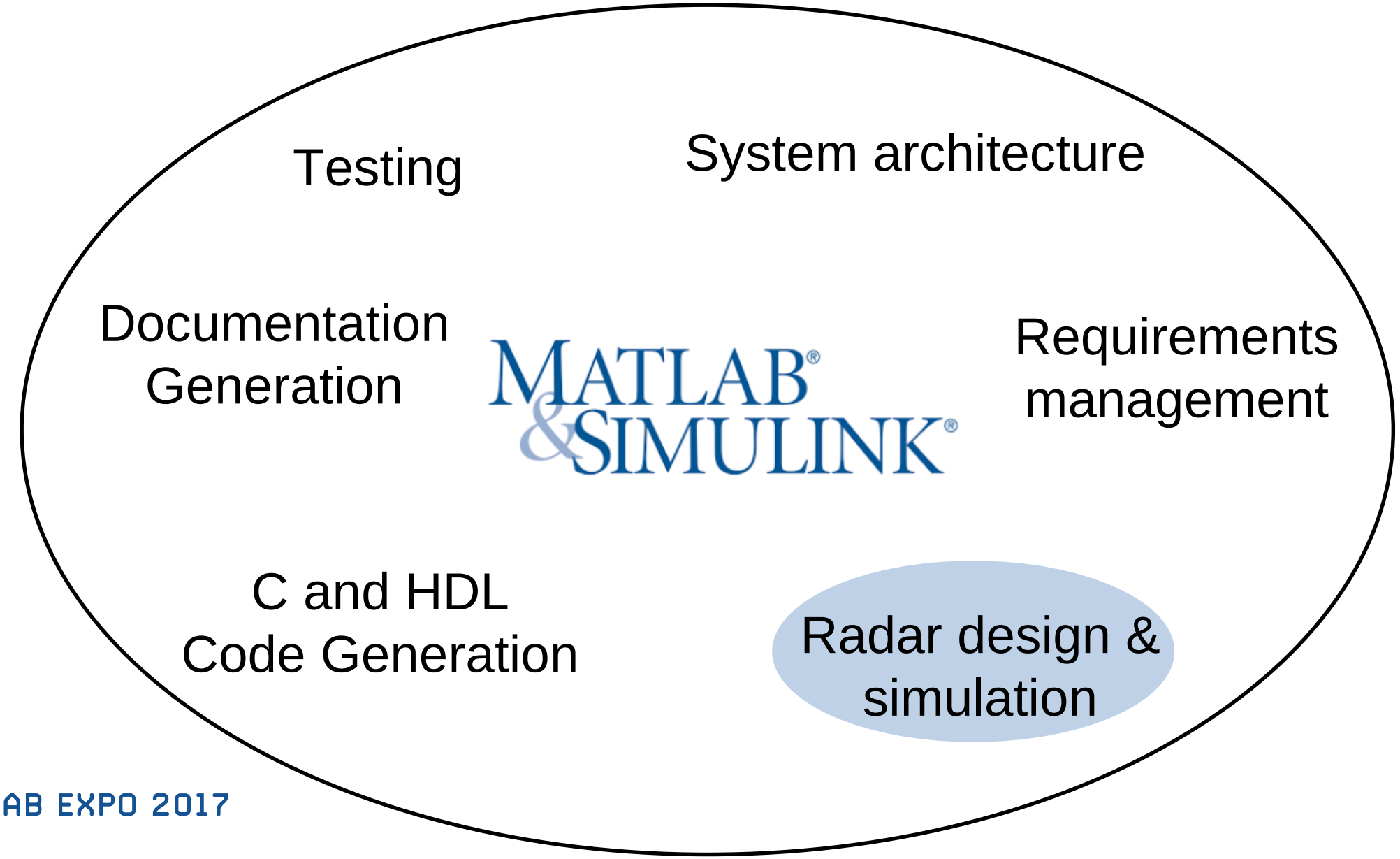
Rick Gentile
Product Manager
Signal Processing and Communications



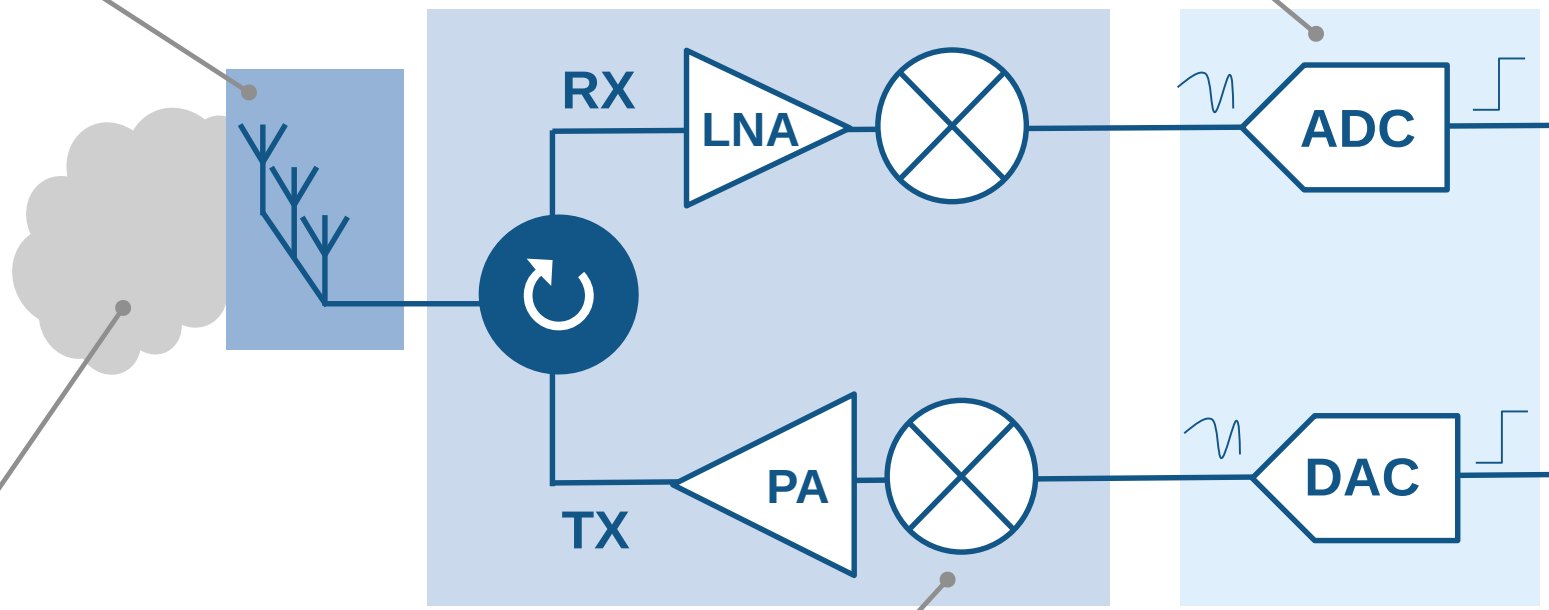
Trends in AESA Radar Systems

- Phased Array technology is pervasive
- Array structures are complex – conformal arrays are required
- Predicting system performance most valuable early in the project
- Requirements for robust operations in the presence of interference
- Wideband applications are expanding rapidly
- Multi-function, multi-domain systems are complex (radar, EW, comms)

Full Coverage of Radar Design Process



Radar System Design: From Antenna to Algorithms



Antenna, Antenna arrays
type of element, # elements, configuration

- Antenna Toolbox
- Phased Array System Toolbox

Mixed-Signal
Continuous & discrete time

- Simulink
- DSP System Toolbox
- Control System Toolbox

Algorithms
beamforming, beamsteering, MIMO

- Phased Array System Toolbox
- Communications System Toolbox
- DSP System Toolbox

- Communications System Toolbox
- Phased Array System Toolbox

Channel - *interference, clutter, noise*

- RF Blockset
- RF Toolbox

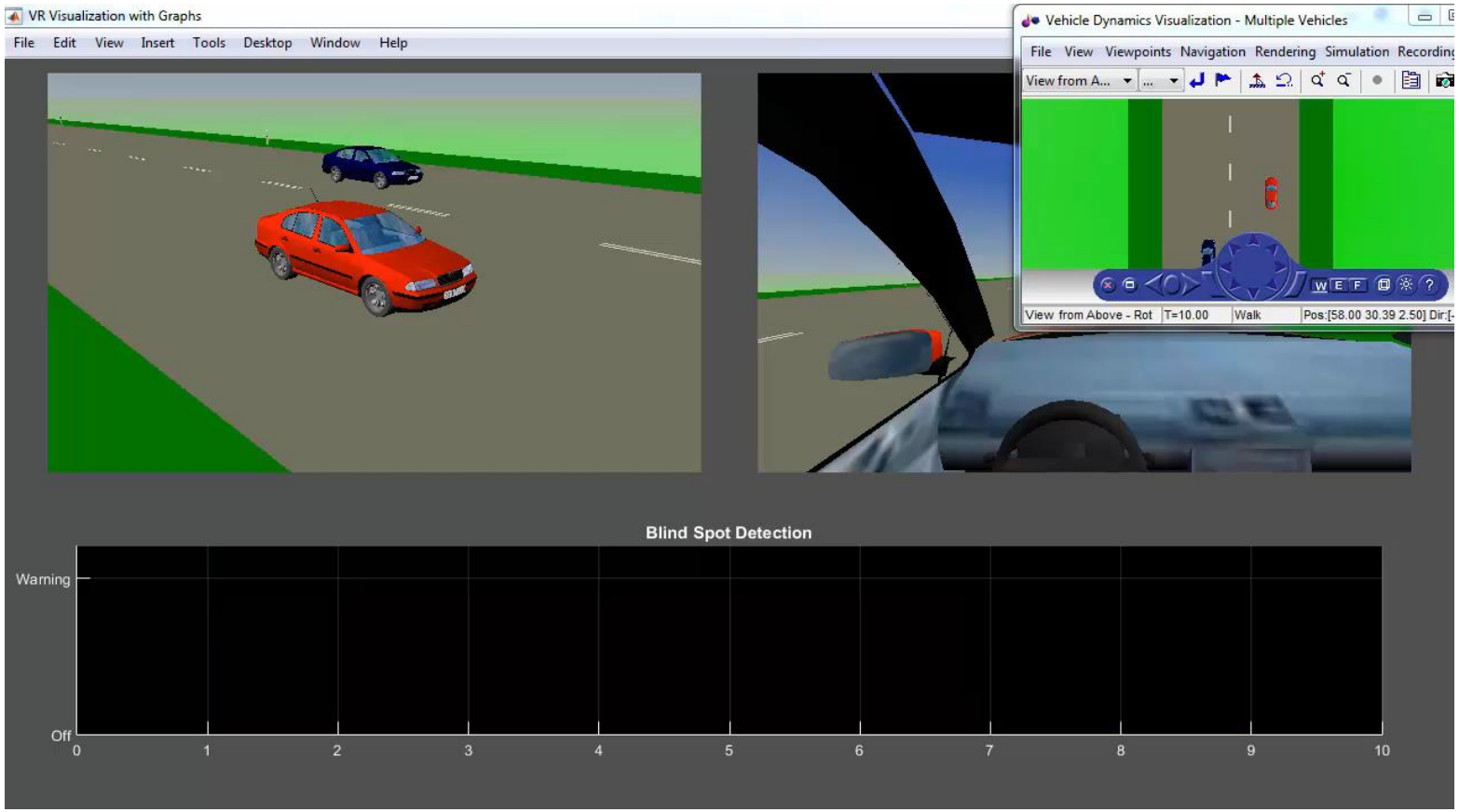
RF Impairments
frequency dependency, non-linearity, noise, mismatches

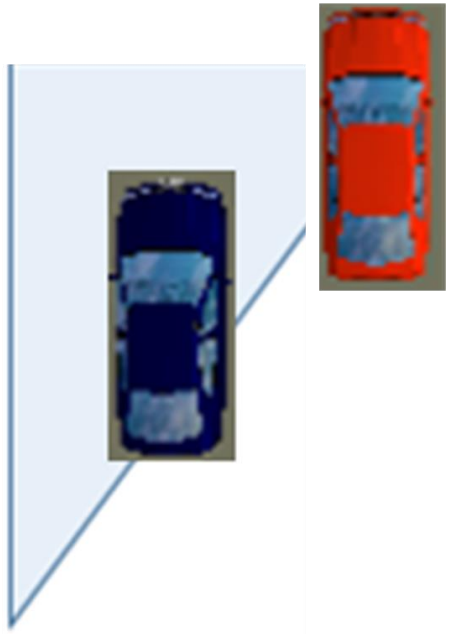
- Phased Array System Toolbox
- Signal Processing Toolbox
- SimEvents
- Instrument Control Toolbox

Waveforms & Resource Scheduling

Automotive Radar Modeling

- How can we use a radar to see this region of interest?

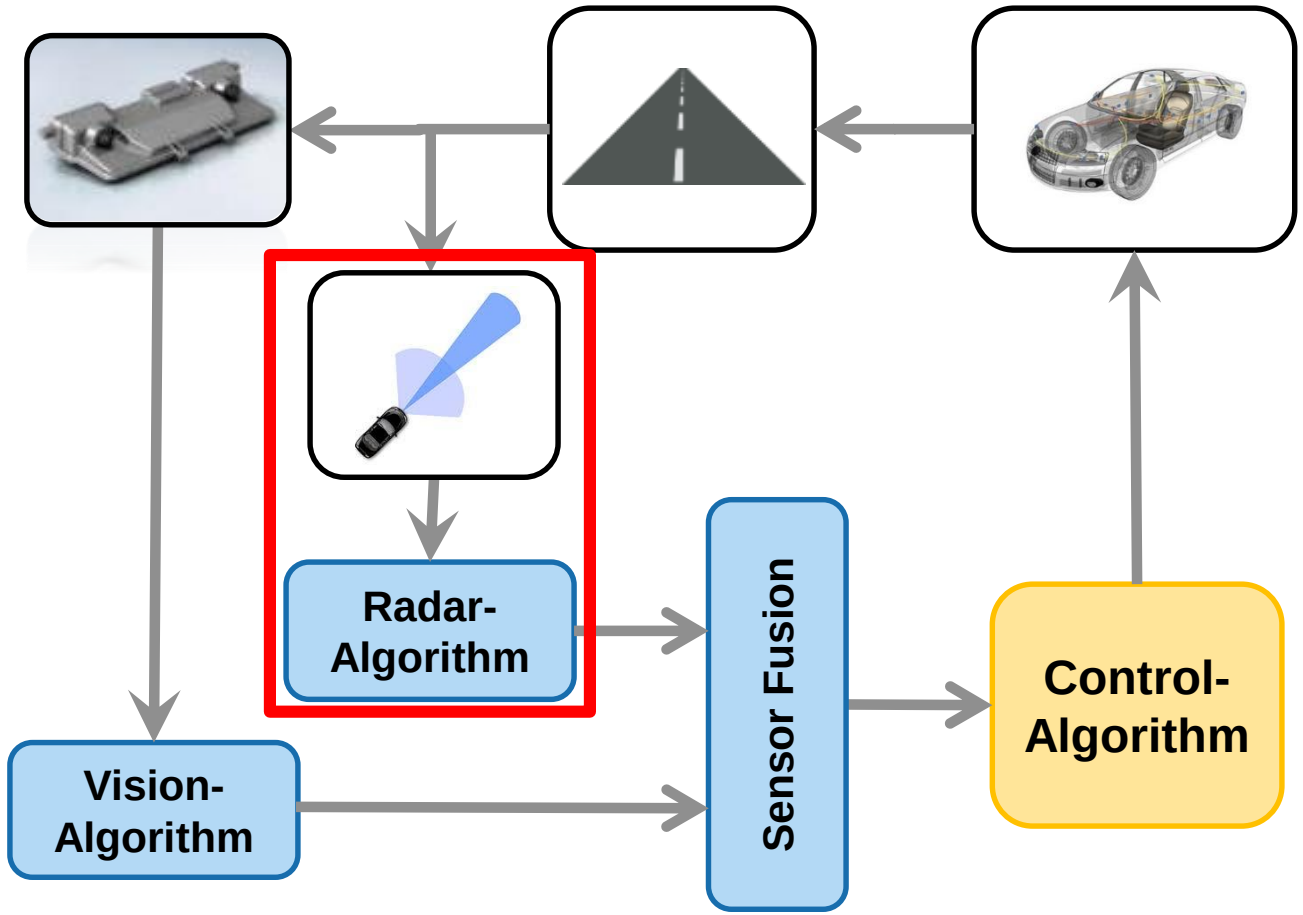




- What kinds of parameters can we determine from a model?
  - Detection
  - Angle of arrival
  - Distance
  - Direction

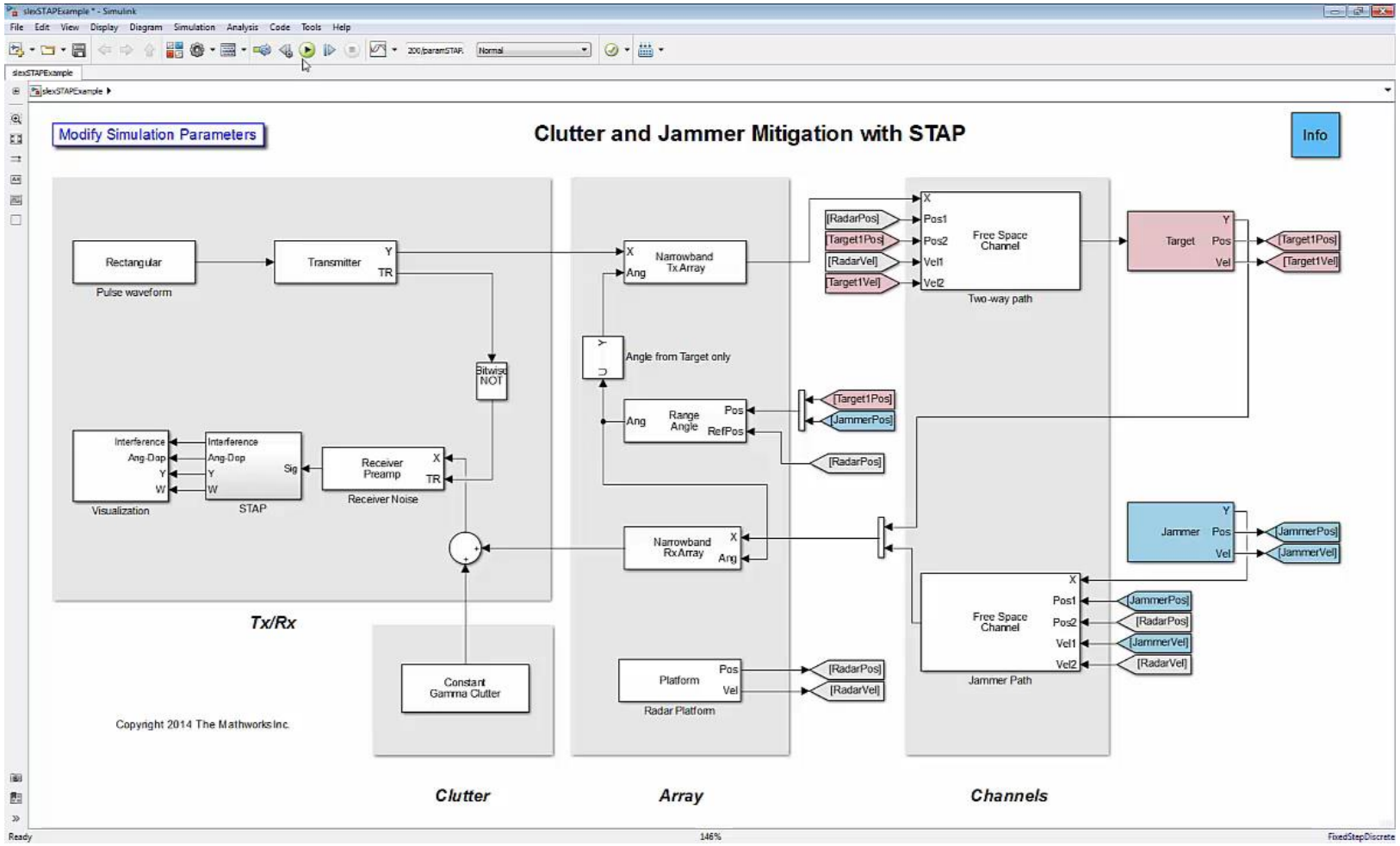
Modeling ADAS Features in Simulink

Integrate sensing (radar, vision, etc…) and control algorithms



Multifunction Space-Time Adaptive Processing (STAP) Radar Model

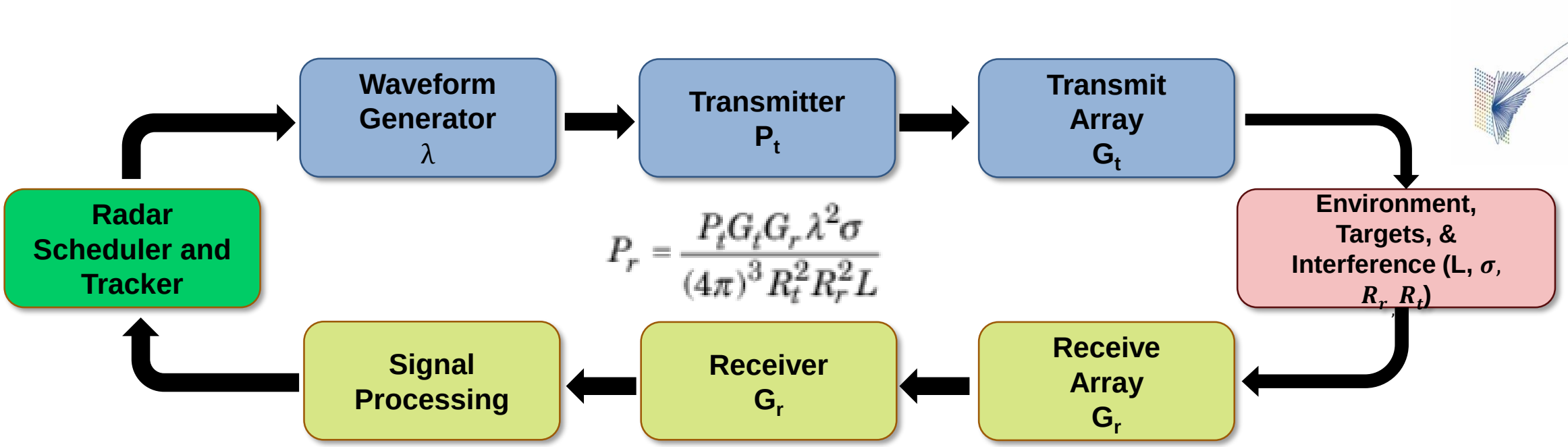
- What is needed to model radar systems?
  - Phased array antenna
  - Receiver/Transmitter
  - Propagation channel
  - Target(s)
  - Interference
  - Clutter
  - Signal processing algorithms



Objectives for MathWorks Radar Simulation Architecture

- Extensible modeling tools for phased array radar design
  - Reduce risk of complex system development
  - Signal level simulation to ensure understanding before system is designed and built
- Multi-domain system modeling for radar systems
  - RF, signal processing, data processing, etc.
- Path to higher fidelity and customization
  - Model should match closely with end system
- Live specification for model-based design
  - Encourage re-use through project phases and across projects
  - Provide early model of system to your customers

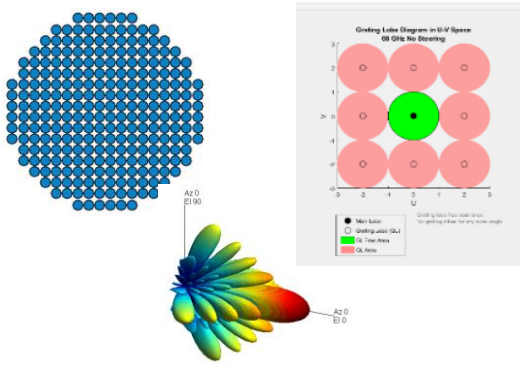
Simulation Framework Overview



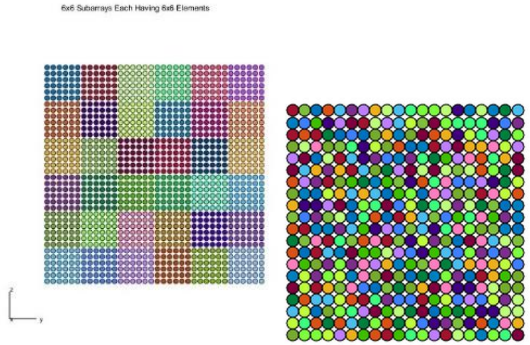
- Functions for calculations and analysis
- Apps for common workflows
- Parameterized components for system modeling
- Code generation for deployment

Array Modeling

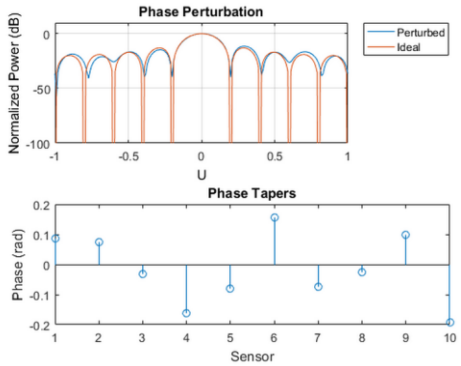
Design an array



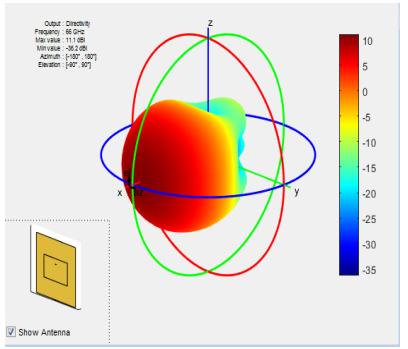
Design subarrays



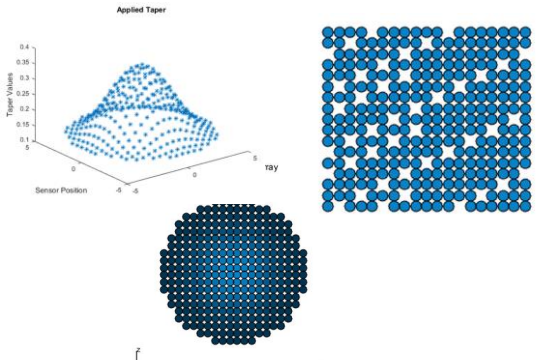
Model imperfections



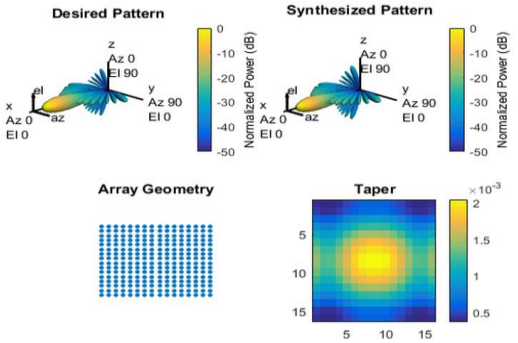
Import antenna patterns



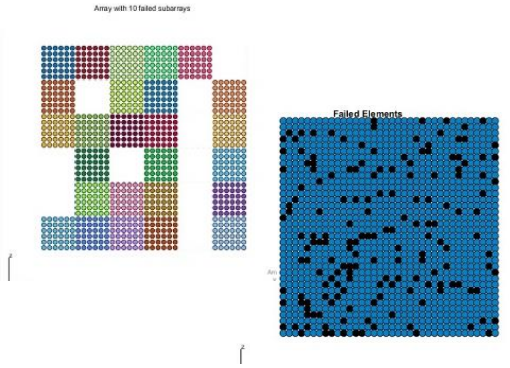
Taper/thin arrays



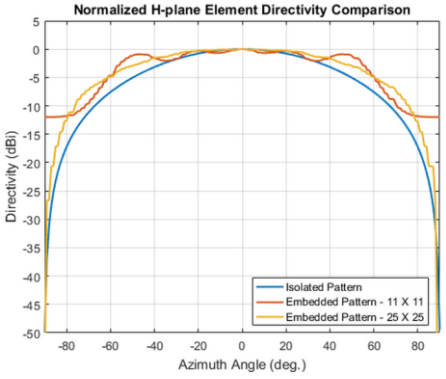
Synthesize arrays



Model failures

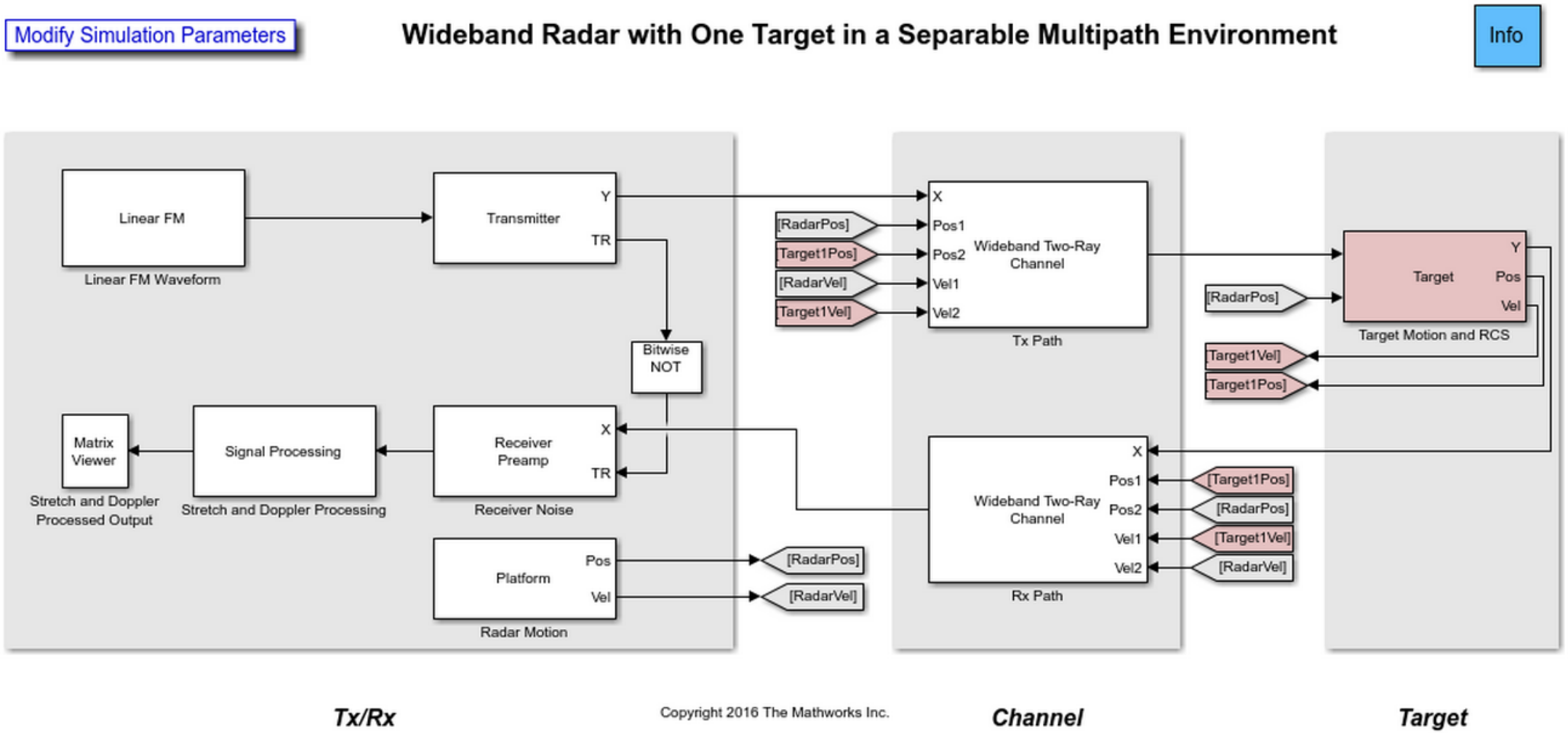


Model mutual coupling



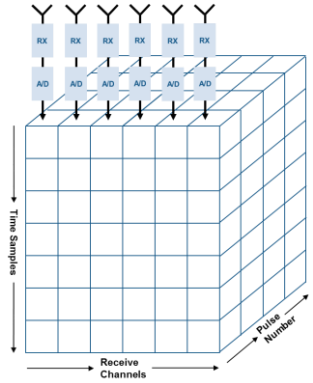
Similar capabilities for other radar components

System Level Validation

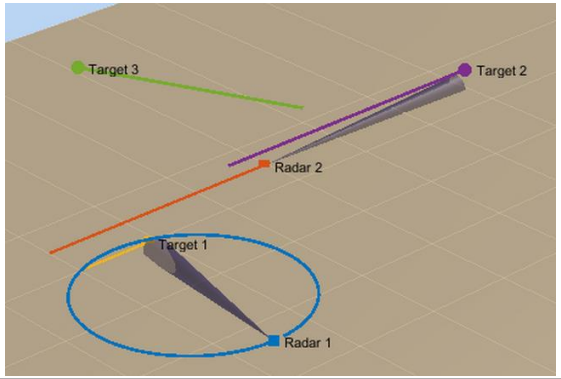


Supporting Capabilities for Radar Systems

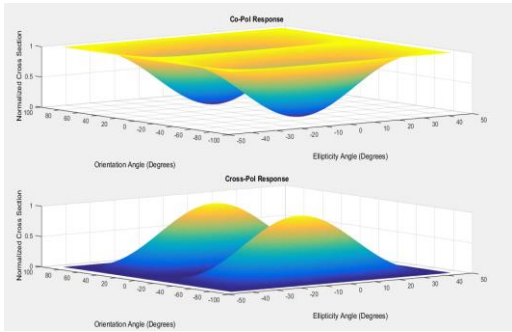
Data cube processing



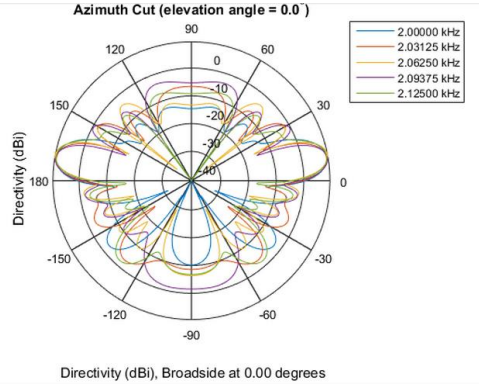
Scenario visualization



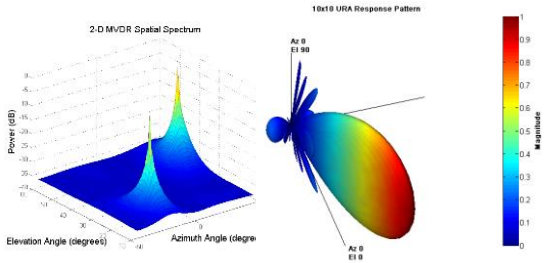
Polarization



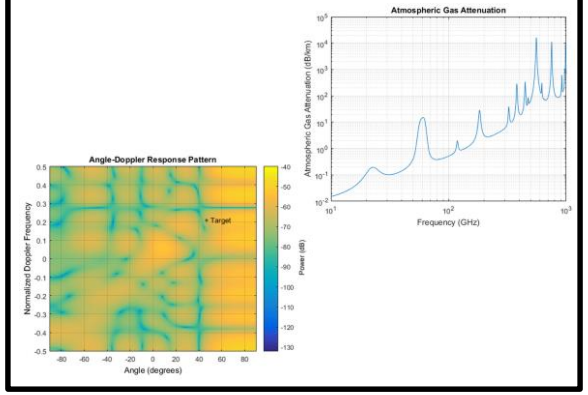
Wideband



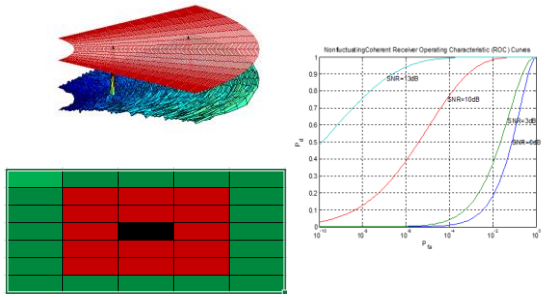
Spatial signal processing



Environment



CFAR



Code generation

C

MATLAB

HDL

Path to Higher Fidelity

- Extend model fidelity over project evolution

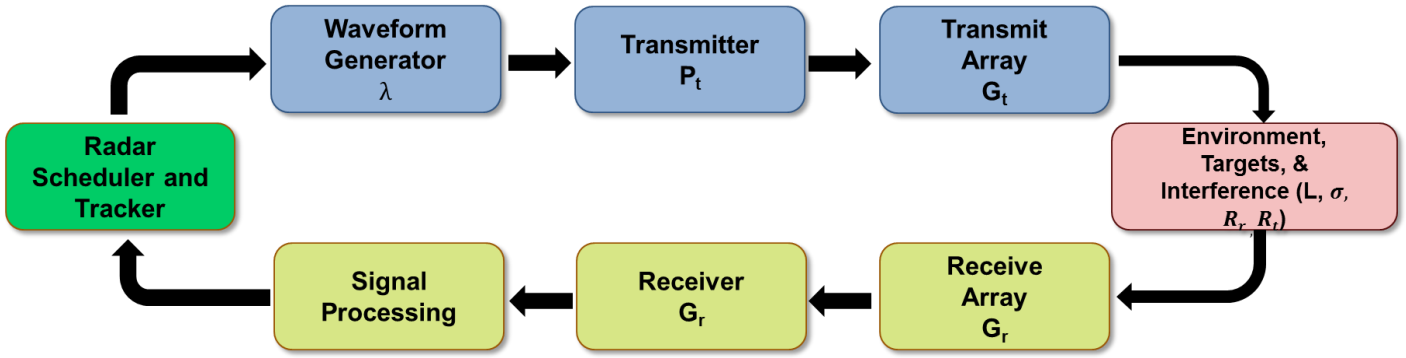
Antenna element	Target model	Propagation model	RF signal chain
Ideal elements	Point target	Free space	Baseband
EM solver with mutual coupling	Synthesized backscatter (angle & frequency)	Line of sight atmospheric effects	RF components
Measured pattern import	Measured return (angle & frequency)	Multipath, terrain and ducting effects	Multi-domain simulation

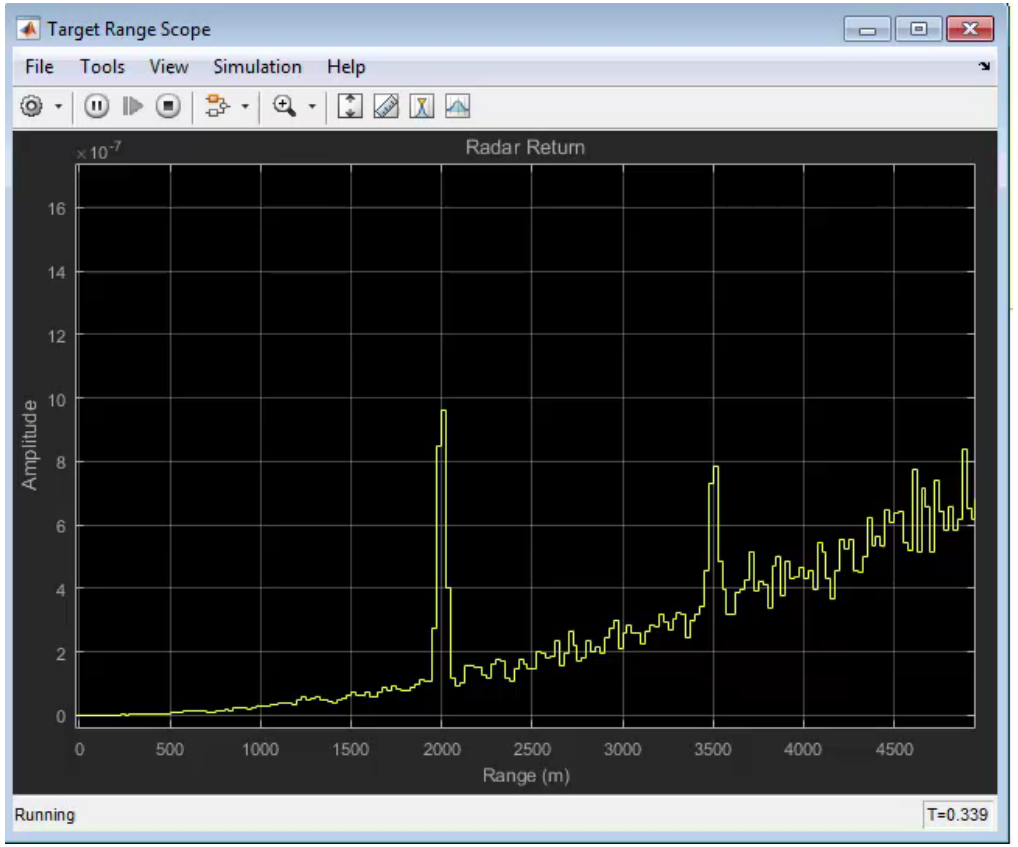
- Simple interface to replace off-the-shelf components with custom ones

Case Studies: Staggered PRF Radar

Dynamic PRF/Waveform selection based radar detections

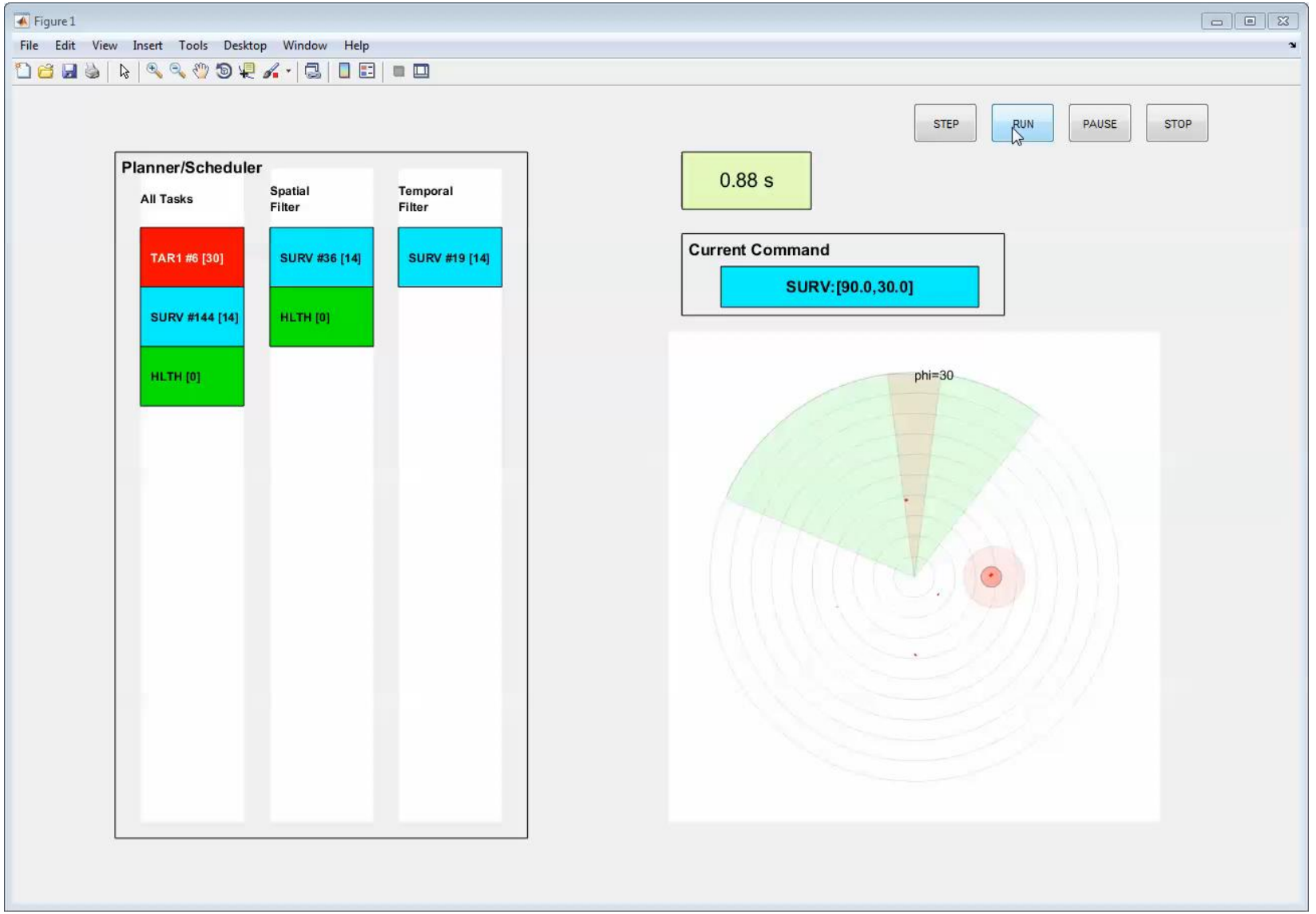
Closed loop between radar model and scheduler





Case Studies: Modeling a Radar Scheduler

Dynamic & static events

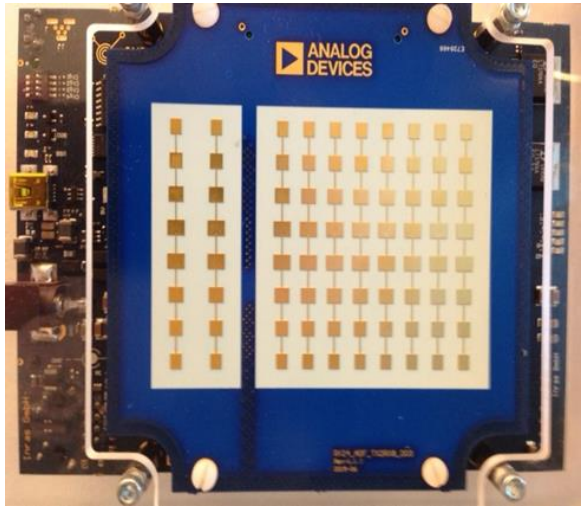


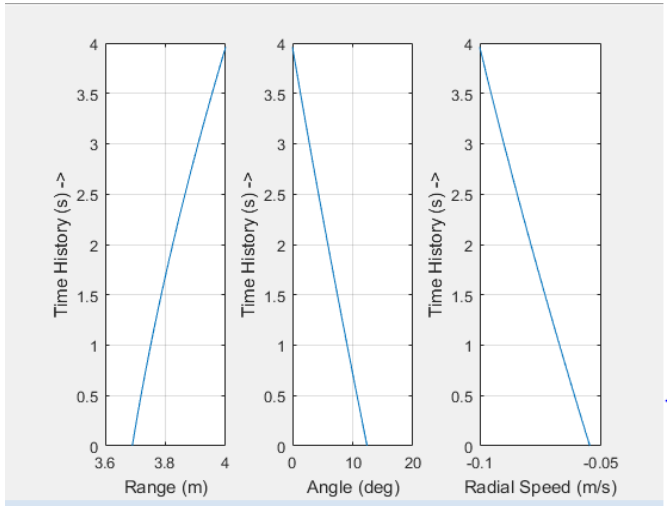
Case Studies: Model-Based Design of an MTI Radar

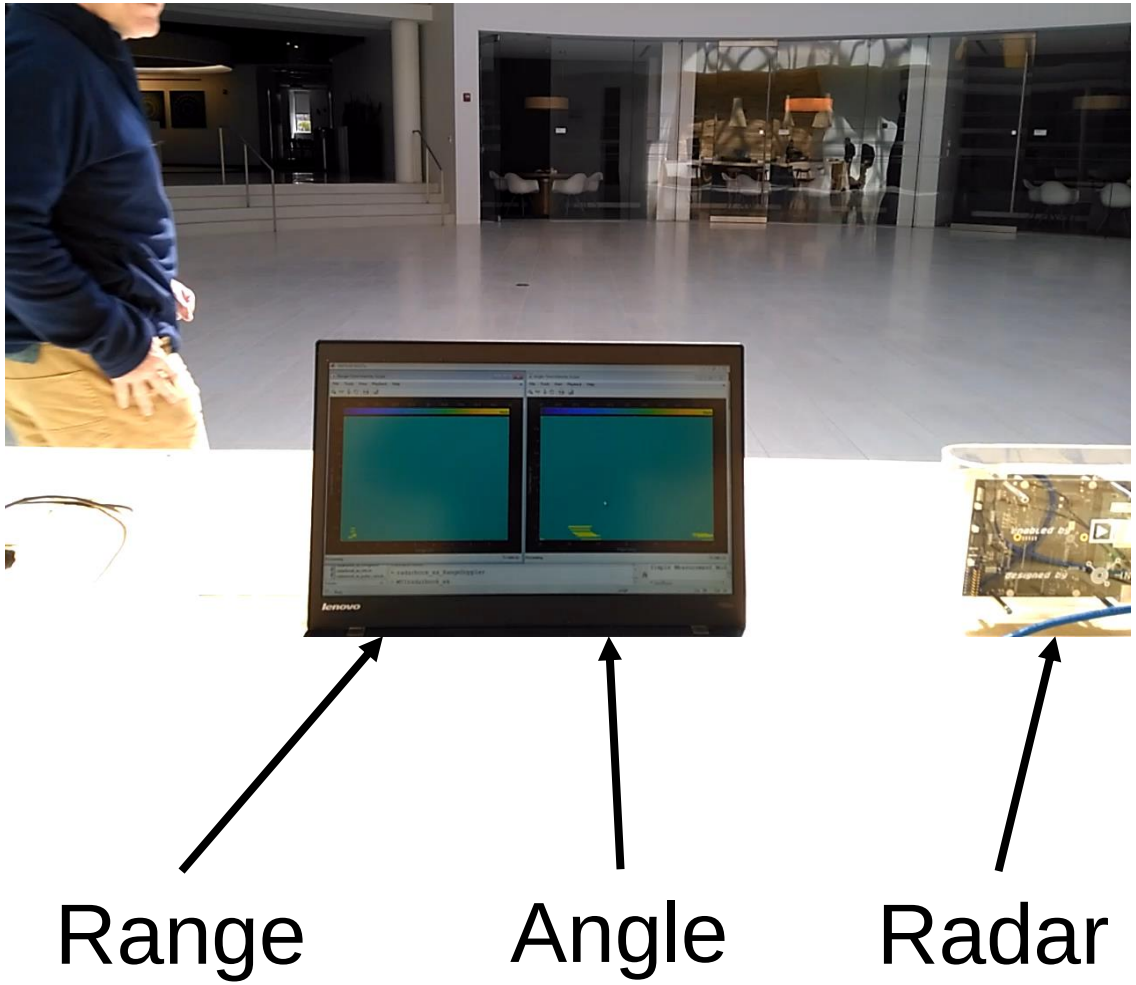
Develop and test with synthesized data

Verification with measured data

8 channel Rx array

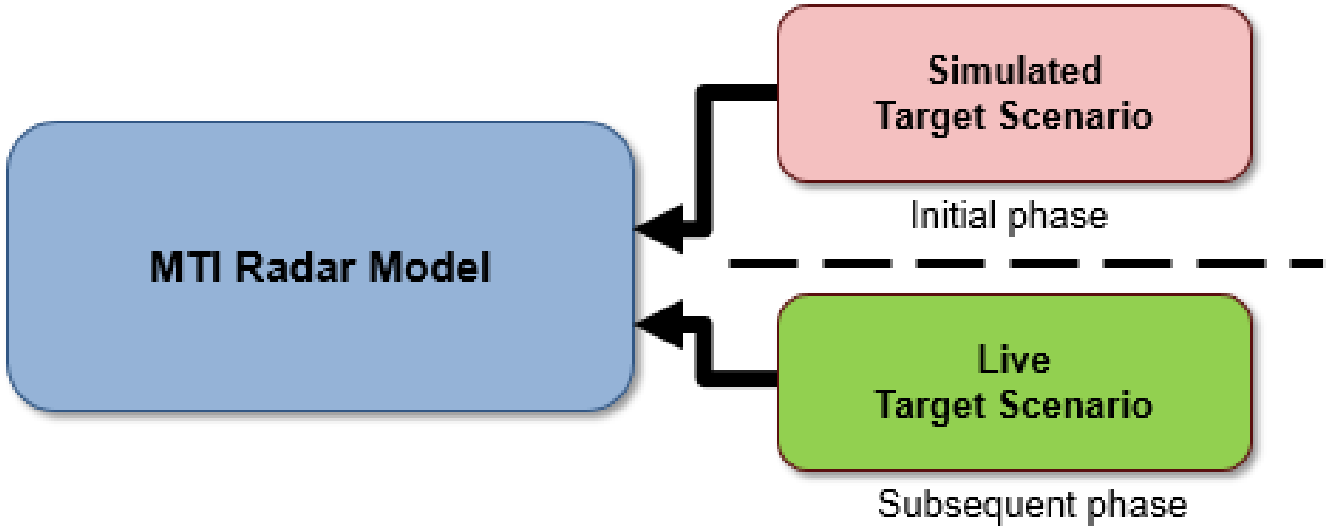


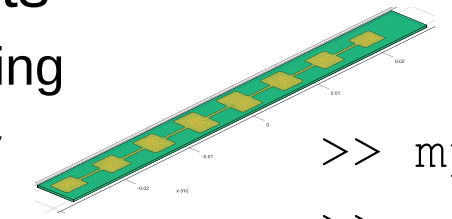




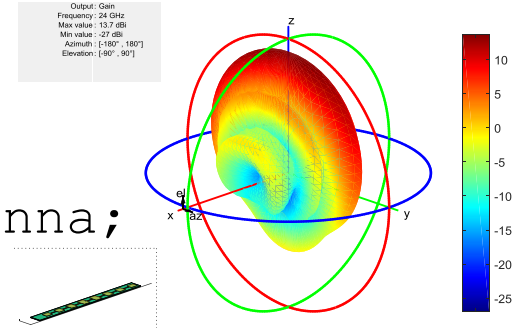
Workflow

- Model-based simulation for algorithm development and validation
  - Scenario synthesis
  - Detection thresholds, CFAR, Beamforming, DOA
- Moving Target Indication
  - Pulse canceller
- Range-Doppler processing
- Antenna effects
  - Mutual coupling
  - Model fidelity





```
>> myURA = phased.URA;
>> myURA.Element = customAntenna;
```



Summary

- Building phased array radar systems is easier with MathWorks tools
  - Phased Array System Toolbox
  - Antenna Toolbox
  - RF Blockset
- Many examples to get started with
- Thank you for attending and please visit our demo station

Explore these examples and more online:
mathworks.com/phased-array-examples

- *Antenna Array Analysis with Custom Radiation Pattern*
- *Array Pattern Synthesis*
- *Mutual Coupling in Large Arrays*
- *Space-Time Adaptive Processing*
- *Designing a Monostatic Pulse Radar*
- *Ground Clutter Mitigation with MTI Radar*
- *Simulating a Bistatic Polarimetric Radar*

Radar System Design: *mathworks.com/radar*

What You Can Do to Learn More

Phased Array System Toolbox

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Design and simulate phased array signal processing systems

Phased Array System Toolbox™ provides algorithms and apps for the design, simulation, and analysis of sensor array systems in radar, sonar, wireless communications, and medical imaging applications. The system toolbox includes pulsed and continuous waveforms and signal processing algorithms for beamforming, matched filtering, direction of arrival (DOA) estimation, and target detection. It also includes models for transmitters and receivers, propagation, targets, jammers, and clutter.

The system toolbox lets you model the dynamics of ground-based, airborne, or ship-borne multifunction radar systems with moving