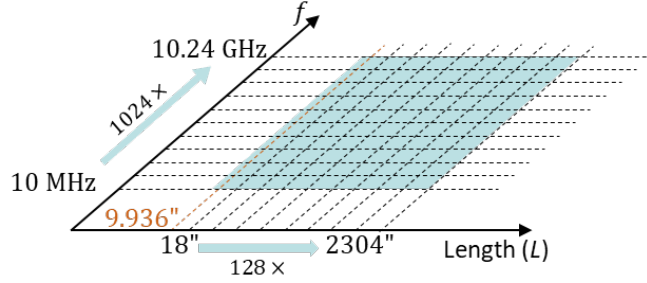**Description of Scattering Object**
A perfect electrically conducting (PEC) almond proportional to the dimensions in [1].

Length Scale and Frequency Range

The problems of interest cover a range of ~256x in physical length scale and 1024x in frequency; the ranges are logarithmically sampled to yield 99 scattering problems. Because the almonds are PEC, there are only 19 + 12 unique scattering problems in Problem Set IIIA. In these problems, the almond sizes are in the range $0.0076 \le L/\lambda_0 \le 1998$, where λ_0 is the free-space wavelength.

Interesting Features
1. The logarithmic sampling is distorted along the length axis for the smallest almond: the smallest almond has L=9.936'' (instead of L=9 in) because of publicly available measurement data corresponding to this size [1],[2]. The sampling is also distorted along the frequency axis: scattering from the smallest almond at frequencies $f \in \{10, 20, 40, 80, 160, 320, 640, 1280, 2575, 5125, 7000, 10250\}$ MHz are included in the problem set because of publicly available measurement data [2]. These distortions add 12 unique scattering problems to the set.
2. The non-trivial shape and tip of the almond presents modeling and meshing challenges.
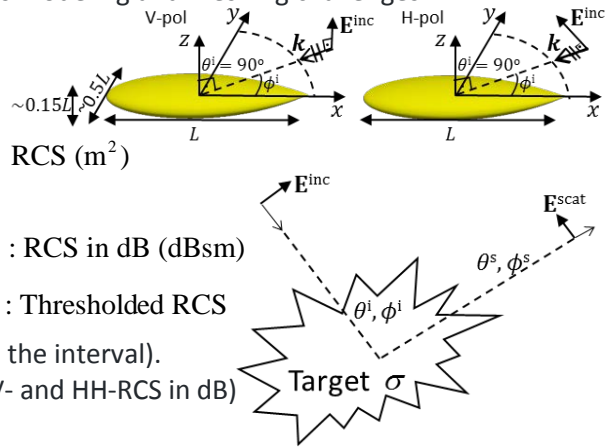
Quantities of Interest
Radar cross section (RCS) definition

$$\sigma_{vu}\left(\theta^s,\phi^s,\theta^i,\phi^i\right)=\lim_{R\to\infty}4\pi R^2\frac{\left|\hat{v}\left(\theta^s,\phi^s\right)\cdot\mathbf{E}^{scat}\left(\theta^s,\phi^s\right)\right|^2}{\left|\hat{u}\left(\theta^i,\phi^i\right)\cdot\mathbf{E}^{inc}\left(\theta^i,\phi^i\right)\right|^2} \quad : \text{ RCS (m}^2)$$

$$\sigma_{vu,\mathrm{dB}}\left(\theta^s,\phi^s,\theta^i,\phi^i\right)=10\log_{10}\sigma_{vu} \qquad : \text{RCS in dB (dBsm)}$$

$$\sigma_{vu,\mathrm{dB}}^{TH}\left(\theta^s,\phi^s,\theta^i,\phi^i\right)=\max(\sigma_{vu,\mathrm{dB}},TH_{vu,\mathrm{dB}})-TH_{vu,\mathrm{dB}} \qquad : \text{Thresholded RCS}$$

1. Set $\theta^i = 90^o$. Vary $0^o \le \phi^i \le 180^o$ (every 0.5^o in the interval).
2. Compute back-scattered $\sigma_{\theta\theta,\mathrm{dB}}$ and $\sigma_{\phi\phi,\mathrm{dB}}$ (the VV- and HH-RCS in dB) at $N_\phi = 361$ scattering directions.

Performance Measures
Error Measure: Simulation errors shall be quantified using

$$avg.err_{uu,\mathrm{dB}}^{TH}=\frac{1}{2\pi}\int_0^{2\pi}\left|\sigma_{uu,\mathrm{dB}}^{TH}\left(\phi^s\right)-\sigma_{uu,\mathrm{dB}}^{\mathrm{ref},TH}\left(\phi^s\right)\right|d\phi^s\approx\frac{1}{N_\phi}\sum_{n=1}^{N_\phi}\left|\sigma_{uu,\mathrm{dB}}^{TH}\left(\phi^s\right)-\sigma_{uu,\mathrm{dB}}^{\mathrm{ref},TH}\left(\phi^s\right)\right| \quad (\mathrm{dB}) \text{ for } u\in\{\theta,\phi\}$$

where

$$TH_{uu,\mathrm{dB}}=\max_{\phi^s}\sigma_{uu,\mathrm{dB}}^{\mathrm{ref}}-80 \ (\mathrm{dB})$$

This error measure discounts errors in RCS values below TH.
Cost Measure: Simulation costs shall be quantified using observed wall-clock time and peak memory/core

$$t_{\mathrm{main}}^{\mathrm{wall}} \text{ (s) and } mem_{\mathrm{main}}^{\mathrm{maxcore}} \text{ (bytes)}$$

as well as the "serialized" CPU time and total memory requirement

$$t_{\mathrm{main}}^{\mathrm{total}} = N_{\mathrm{proc}} \times t_{\mathrm{main}}^{\mathrm{wall}} \text{ (s) and } mem_{\mathrm{main}}^{\mathrm{max}} = N_{\mathrm{proc}} \times mem_{\mathrm{main}}^{\mathrm{maxcore}} \text{ (bytes)}$$

Here, N_{proc} denotes the number of processes used in a parallel simulation. It is expected that results will be reported for at least 2 runs: "Efficient" (small N_{proc}) and "Fast" (large N_{proc}).

Study 1: Error vs. Cost Sweep
Fix frequency and fix almond dimensions. Simulate many error levels (proxy: mesh densities) for 4 cases:
Case 1: f=10 MHz, L=9.936 in   Case 2: f=7 GHz, L=9.936 in
Case 3: f=10 MHz, L=288 in   Case 4: f=320 MHz, L=288 in
It's recommended to simulate as many error levels (mesh densities) as possible. 3-5 error levels is typical. A typical error-vs.-cost study will consist of 4x3-5=12-20 simulations.

Study 2: Frequency Sweep
Fix almond dimensions and error level (proxy: mesh density). Simulate many frequencies for 4 cases:
Case 1: L=18 in, error level 1 (coarsest mesh)   Case 2: L=288 in, error level 1 (coarsest mesh)
Case 3: L=18 in, error level 2 (finer mesh)   Case 4: L=288 in, error level 2 (finer mesh)
Frequencies shall be chosen as $f \in$ {10, 20, 40, … , 5120, 10240} MHz. It's recommended to simulate as many frequencies as possible. A full frequency-sweep study will consist of 4x11=44 simulations.

Study 3: Size Sweep
Fix frequency and error level (proxy: mesh density). Simulate many sizes for 4 cases:
Case 1: f=10 MHz, error level 1 (coarsest mesh) Case 2: f=320 MHz, error level 1 (coarsest mesh)
Case 3: f=10 MHz, error level 2 (finer mesh)   Case 4: f=320 MHz, error level 2 (finer mesh)
Dimensions shall be chosen as $L \in$ {9.936, 18, 36, … , 1152, 2304} in. It's recommended to simulate as many sizes as possible. A full size-sweep study will consist of 4x9=36 simulations.

Reference Quantities of Interest
The following RCS data are made available in the benchmark to enable participants to calibrate their simulators:

8 RCS measurement results corresponding to the smallest almond (L=9.936 in) at frequencies $f \in$ {2575, 5125, 7000, 10250} MHz. These measurements were made using two almonds [2]: one was of size L=9.936 in and the other was scaled up 2x in all dimensions. These data are the same as those plotted in Figs. 11-12 of [2]; they are provided for ϕ^{i} sampled every 0.25^{o}.

4 RCS simulation results for the smallest almond at the above 4 frequencies found by using the ARCHIE-AIM code, a frequency-domain FFT-accelerated integral-equation solver developed at UT Austin [3]-[5]. These data are the same as the finest mesh ($\approx$0.6-mm average edge length) results in [2].

References
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[3] M. F. Wu, G. Kaur, and A. E. Yılmaz, "A multiple-grid adaptive integral method for multi-region problems," *IEEE Trans. Antennas Propag.*, vol. 58, no. 5, pp. 1601-1613, May 2010.
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[5] J. W. Massey, V. Subramanian, C. Liu, and A. E. Yılmaz, "Analyzing UHF band antennas near humans with a fast integral-equation method," in *Proc. EUCAP*, Apr. 2016.