Tool for RCS Analysis, Computation, and Simulation (TRACS)

David R. Bergman, PhD

Exact Solution Scientific Consulting LLC, Picatinny Technology Innovation Center, Dover NJ, USA

Introduction

Simulated RCS data is used in a variety of end to end simulations relevant to the defense industry, as well as in the design and performance prediction of radar systems. The process can be time consuming, requiring the development of a CAD model of the threat object for use with a computational electromagnetics solver, *e.g.* method of moments (MoM) or a shooting bouncing ray trace (SBR) method. Look-up tables are generated for multiple frequencies and angles, and often converted to scattering center models. A drawback to the standard approach is that if a change is made to the threat object the process usually needs to start from step one. The goals of this research and development effort are:

- Morph existing facet files to generate new shapes using a set of morphing algorithms
- Develop a perturbative MoM solver for evaluating the RCS of the morphed objects using prior data
- To optimize existing MoM algorithms to increase speed and reduce memory footprint

Theory

Abstract representation of RCS dependence on object geometry

$RCS[G]$

RCS, output of CEM solver — Geometry, input to CEM solver

Change in input geometry produces a change in RCS

$$\delta RCS = RCS[G + \delta G] - RCS[G]$$

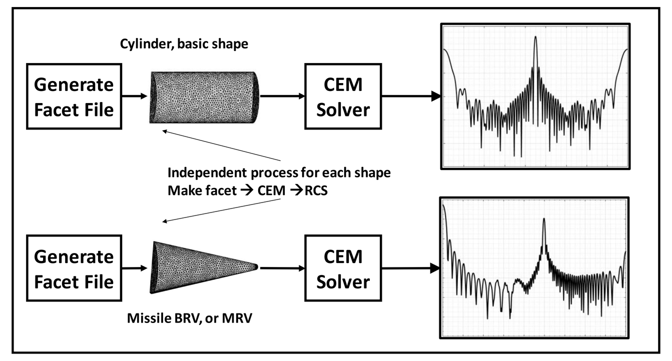
Change in RCS — Moved facets, altered material type, etc.

Perturbation in formalism produces "corrections" to RCS

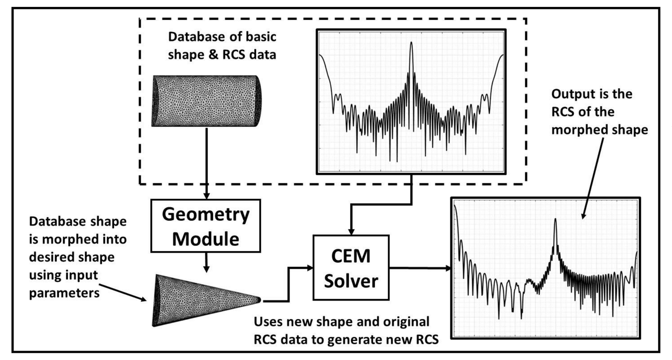
$$\delta RCS = \frac{\delta RCS}{\delta G} + \cdots$$

δRCS and initial RCS are combined — This term comprises the majority of our research

A perturbation series is derived relating the changes in the EFIE and MFIE operators to the change in facet geometry. Morphing functions are applied to facets and the change in MoM output determined.

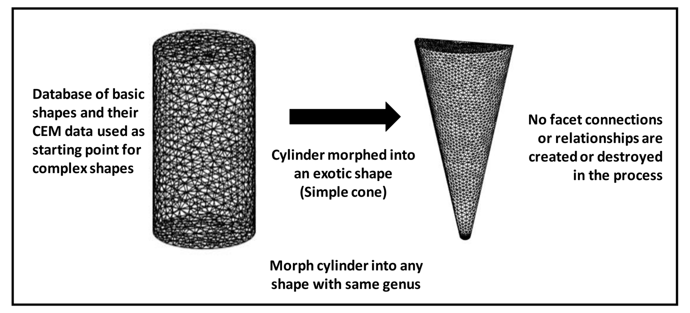


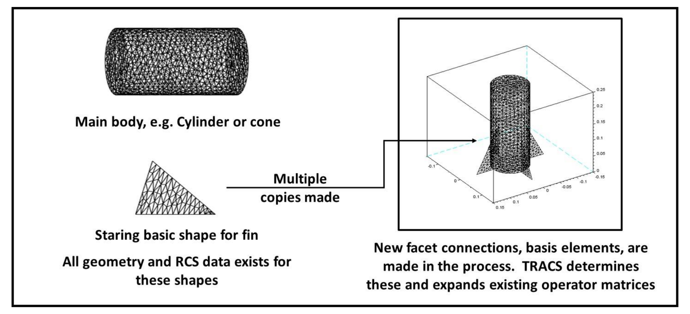
Work flow for RCS data generation process. Each shape is an independent job requiring new or edited CAD models and a running a CEM solver from scratch to generate RCS tables.

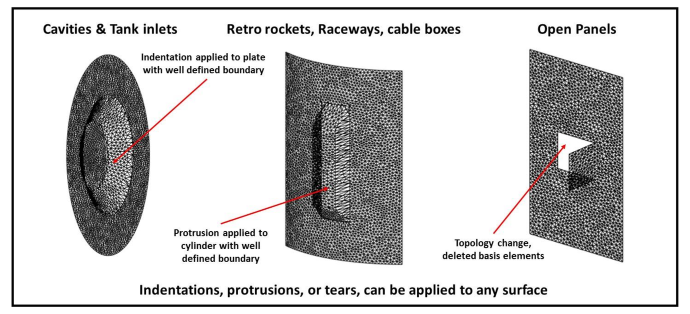


In this approach existing shape and RCS data are used to generate data for new shapes via a morphing procedure. RCS data is calculated using one of many perturbation methods.

Morphing Types

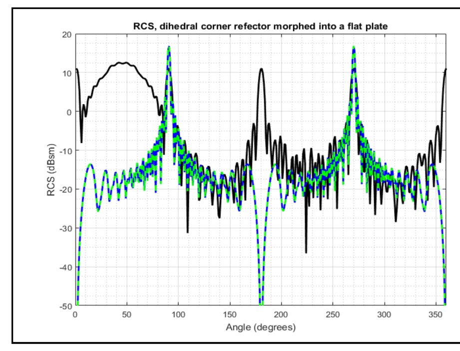


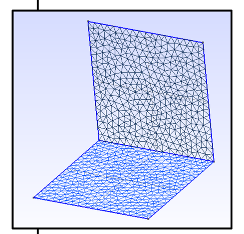




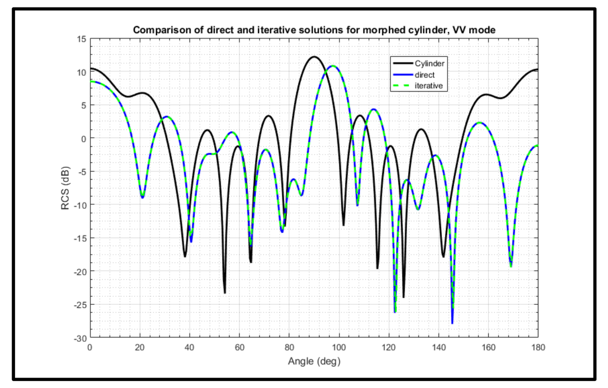
Morphing is done by software, eliminating the need for manual effort. There are three types of morphing functions. The first (top) are large scale changes that preserve topology, *e.g.* cylinder to simple cone. The second (middle) involve fusing different objects together to create a compound object, *e.g.* placing fins on a cylinder. The third type (bottom) involve embellishing the surface of an existing object to create details, *e.g.* cable boxes, cavities, *etc.* The goal is to be able to build up a detailed model of a realistic object staring with basic shapes.

Research Examples

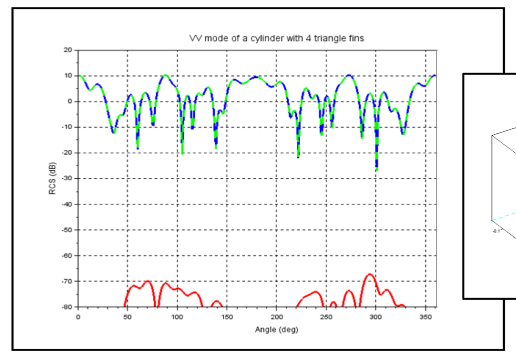


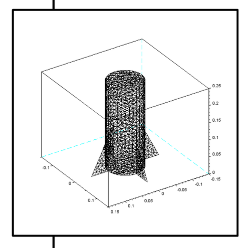


A corner reflector (black) is deformed into a flat plate in steps of 2 deg. Shown are the RCS from a direct solver (blue), and the RCS from TRACS (green).



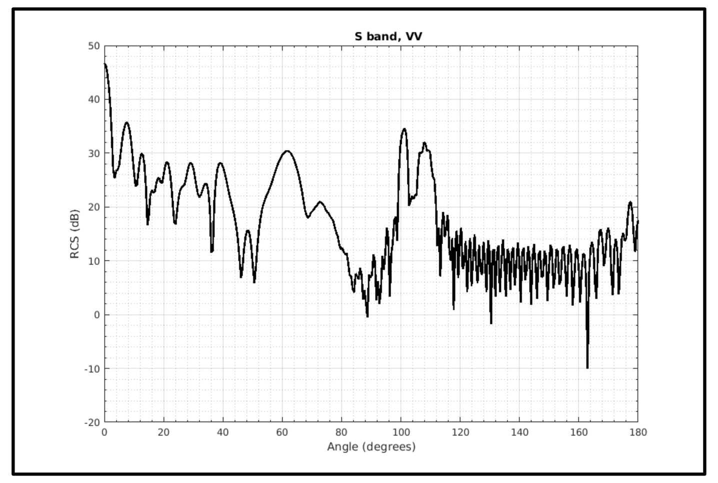
A cylinder (black) is morphed into a novel shape. Shown are the RCS from a direct solver (blue), and the RCS from TRACS (green).





A composite object made of a cylinder and 4 fins. Shown are the RCS from a direct solver (blue), the RCS from TRACS (green), and the coherent difference (red).

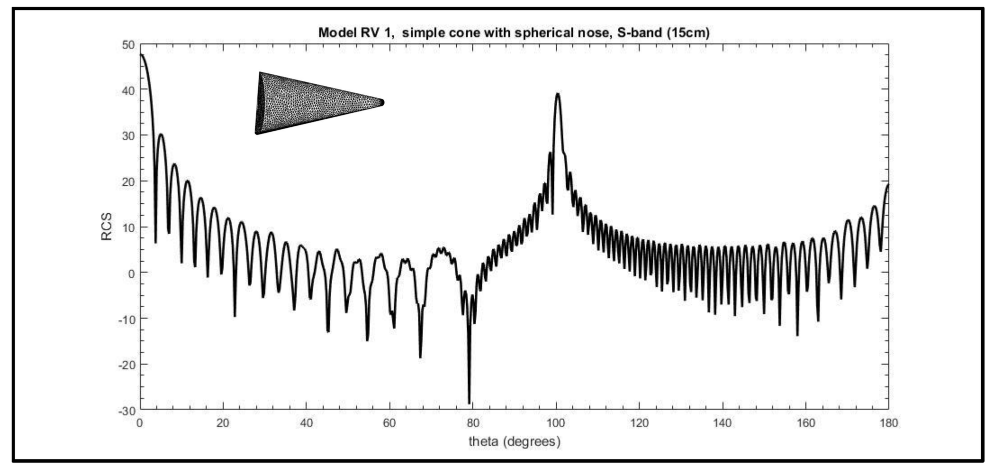
Benchmark

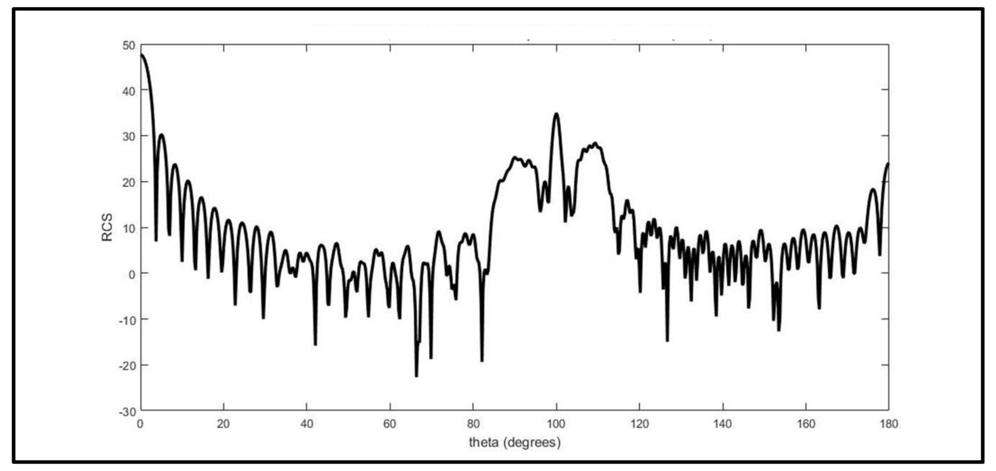


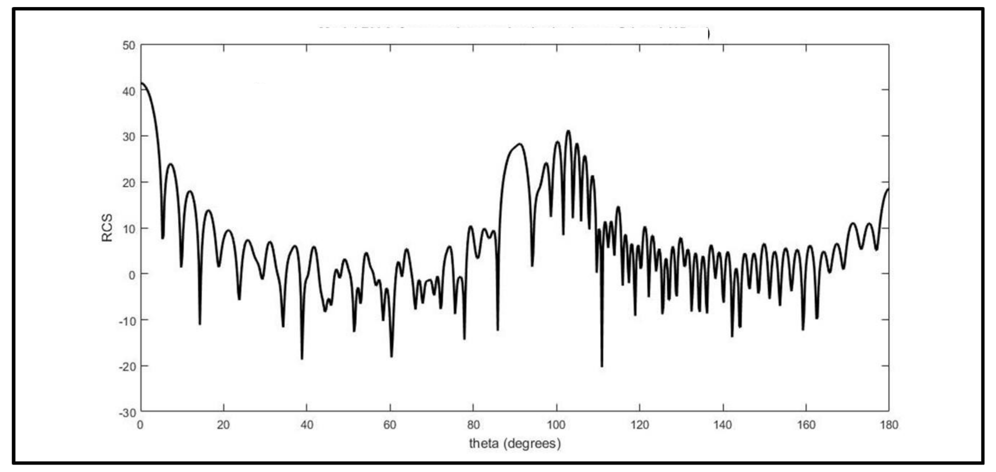
The CEM solver developed for this effort was benchmarked using data supplied by Leidos Inc., from two types of CEM tools (one SBR, the other a full wave solver). Shown here is the output from TRACS, which had excellent agreement with the full wave data.

Example – Shapes

The following set of examples involves models morphed from a large cylinder. The maximum length (width) of the first example is ~3.5m (1.4m), and λ = 15cm.







Optimizations

List Of Optimizations in TRACS	
Optimization	**Performance**
Self coupling	Speed up by factor of 8.5
Numerical Integration	Speed up by factor of 17
Perturbative operator fill	Speed up by factor of 47
Use of prior data	Reduce iteration by factor of 10
Higher-order methods	Fill time reduced by 20
	Memory reduced by 200

Conclusion

In its initial phase TRACS has demonstrated the ability to morph existing objects and their RCS. Perturbative and iterative solvers provide good fidelity compared to direct solutions for new shapes. The use of prior data allows many aspects of the modeling process to be circumvented, shortening process and run time. For the types of geometries investigated most morphing was possible with a cylinder as the initial shape and required no manual effort. Current research is geared towards extended the modeling paradigm to a greater variety of shapes, and parallelization of existing algorithms.

References

[1] The Method of Moments in Electromagnetics, Second Ed, CRC, W. C. Gibson (2015)

[2] Radar Cross Section, Second Ed, Scitech, Knott et al (2004)

[3] Radar Handbook, Second Ed, McGraw-Hill, Skolnik (1990)

[4] Gmsh, A three-dimensional finite element mesh generator with built-in pre- and post-processing facilities, http://gmsh.info/

Acknowledgments

This work was funded by the missile defense agency (MDA) through a department of defense (DoD) Phase I small business innovative research (SBIR) grant.