Analysis, Analysis Practices, and Implications for Modeling and Simulation

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The Problem

The Department of Homeland Security mission requires an enterprise's systems-of-systems (SoS) analytic capability to allow DHS leaders to gain understanding of the combined effects of cross-component capabilities and processes from an SoS perspective, and to enhance DHS enterprise planning activities (e.g., joint assessment of requirements, strategic programming, acquisition decisions, operational assessments).

The act of identifying, enumerating, evaluating, and mapping known technologies to inferred program requirements is an important foundation to enterprise planning activities.

Background

Virtually all analyses currently performed in DHS—whether to justify an investment, assess the adequacy of an existing capability, or for some other reason—center, if not entirely then almost exclusively, on the individualized assessment of the focal system, platform, or capability. Few, if any, satisfactorily account, in a holistic way, for the mission contributions of related systems or combined effects of the overall SoS. Multiple Government Accountability Office (GAO) reports recognized that DHS core missions would benefit from joint assessments that consider competing and complementary platforms, systems, and activities across the Doctrine, Organization, Training, Materiel, Leadership and Education, Personnel, Facilities and Policy (DOTMLPF) spectrum.

To address this gap, the DHS Science and Technology Directorate is standing up a System of Systems Operational Analytics (SoSOA) investment to establish an analytic framework, designed and developed in partnership with the components and headquarters organizations, through the integration of existing and emerging analytic, modeling, and simulation (M&S) technologies. We describe the SoSOA in terms of an analysis use case, along with some of the analytic and technical challenges the program will need to address.

Analysis Use Case

In general, there are three sources of activities that may result in analysis due to the identification of a gap: a policy directive, an acquisition initiative, and an Inspector General or GAO request. In all three cases, the directive for analysis is assigned to a sponsor or stakeholder responsible for responding to the directive (usually with some kind of analytic activity). The stakeholder often seeks support (e.g., Federally Funded Research and Development Center, University Affiliated Research Center, or internal support) for the analysis, and a fair amount of interplay (e.g., problem definition/scoping, negotiation for resources) must take place to plan and execute the analysis.

Typically, and in the "as-is" case (see Figure 1), the directive does not identify a SoS view, only a single-platform, single-solution view. The needs analyses for the MQ-9 and the Multi-mission Enforcement Aircraft (MEA) are examples of this single platform approach. The quantities and laydown of these complementry aircraft, with overlapping capabilities, were analyzed without regard for each other. This is a common analytic challenge at DHS, where related analyses may spawn multiple directives for multiple studies or analyses, designed and executed by independent organizations using unique methods, tools, or data that are not normalized, not interoperable, and in some cases not even formally assessed for their fitness for use. In cases such as these, decision makers are faced with the difficult task of using independently derived and inherently incomparable analytic results to envisage the combined effects of multiple systems.

In the "to-be" case (see Figure 2), on the other hand, the SoSOA intends to provide a capability set that helps to structure the study planning process to foster the use of normalized and validated tools, methods, and data. In this case, the analytical questions and supporting tools and data can be used to assess the interactions of all systems and their contributions to the overall mission. For example, if the mission contributions of Unmanned Ground Vehicles (UGs) interact with the mission contributions of Integrated Fixed Cameras, the analysis of the two systems jointly will reveal the relationship and allow for a more-refined characterization of the trade space. This insight allows better informed investments—not decided on a system-by-system isolated basis but on the contribution of the pieces to the overall capability.

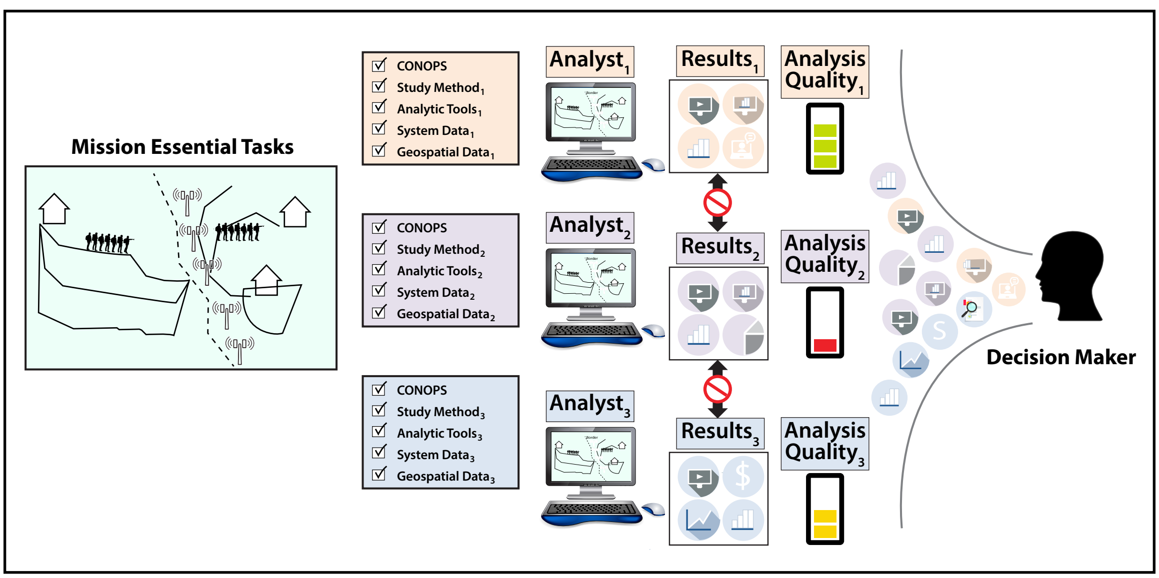

Figure 1. As-Is Analytical Ecosystem at DHS

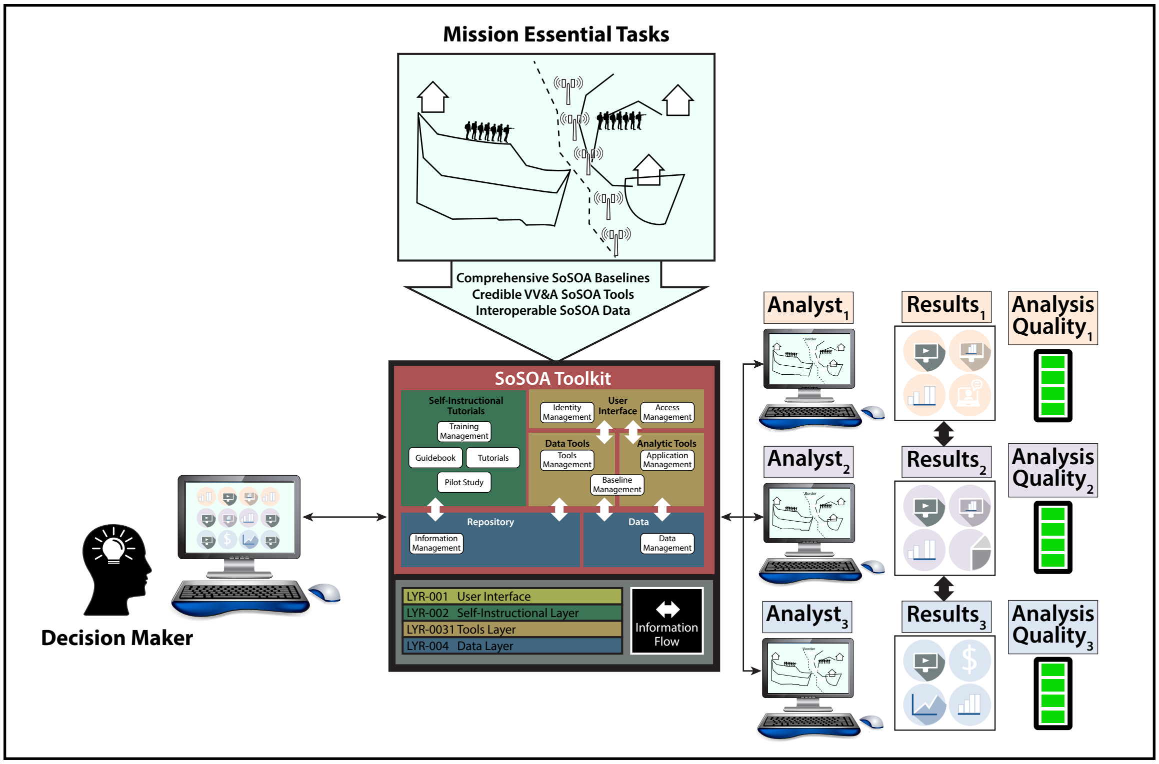

Figure 2. To-Be Analytical Ecosystem with SoSOA

Technology Assessment and Roadmap

IDA has assisted the SoSOA with initial program mission analysis and programmatic documentation by scoping the project and defining high-level technical challenges, identifying and assessing relevant research that may help mitigate technical challenges, and composing a high-level technology roadmap to achieve SoSOA objectives. These documents are largely organized around three technical challenges:

- Systems of systems modeling
- Analytic tools and methodologies
- Computing paradigms.

Systems of Systems Modeling

The maturity of SoS M&S and the maturity of the solutions to its related technical gaps, including a review of existing SoS engineering and integration standards, are described in the SoSOA Apex Tech Scouting Snapshot. Many successful examples of existing solutions and standards provide some assurance that the SoSOA is technically feasible. Part of the technical challenge will be preserving component-specific tools to analyze the capabilities offered by the individual components while simultaneously accurately representing cross-component missions that build on the combined, synergistic effects of these individual capabilities. This will require a careful systems engineering/integration analysis. Above and beyond the reuse of existing M&S capabilities, other technical challenges that could influence the effectiveness and efficiency of any given system's modeling solution include semantic interoperability, correlated representation of the environment, fair fight anomalies, and entity aggregation and disaggregation.

Analytic Tools and Methodologies

In general, the SoSOA toolkit should comprise a variety of tools to provide for robust analysis (Davis and Henninger 2007). Beyond the SoSOA M&S infrastructure, SoSOA is intended to include a number of methodological advancements both to improve analytic forecasts and to serve as a catalyst in striking the right business model for enterprise participation. One of these methodological advancements is ensemble modeling (Henninger, Pratt, and Roske 2006). Ensemble modeling is the process of running a number of related but phenomenologically diverse analytical models and then synthesizing the results to improve the accuracy of the overall system. The maturity of these analytic capabilities and the maturity of the solutions to its related technical gaps are described in the SoSOA Tech Scouting Snapshot.

Computing Paradigms

Finally, the platform on which the SoSOA will be implemented is a technical choice that still must be evaluated. Contemporary efforts similar in scope to SoSOA have used cloud platforms (Henninger 2016), high-performance computing platforms (Bouwens et al. 2012), and SoS modeling efforts in distributed environments based on client-server architectures (Henninger et al. 2008).

After identifying relevant capabilities and applicable technologies across all of these areas and expressing them in terms of maturity and degree of interest to SoSOA, IDA prepared a high-level Technology Roadmap. The Roadmap additionally identified a number of APEX engines and programs that may contribute to the SoSOA capability, and highlighted some of the interrelationships between the various instantiations of these three high-level technical areas. For example, both the simulation architecture and the ensemble architecture would change depending on the computing paradigm adopted.

Conclusion

While only an initial step, the act of identifying, enumerating, evaluating, and mapping known technologies to inferred program requirements is an important foundation to the program. The maturity of these technologies and, in some cases, the existence of similar capabilities, provide some degree of confidence that the undertaking is indeed feasible and achievable within the estimated bounds of program costs, and that the potential payoff in improved capability is worthy of continued research investment at the institutional level.

References

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