Framework for Assurance of Emergent Behaviour for use in Autonomous Robotic Swarms

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Abstract—Abstract of the paper.

Index Terms—Assurance, swarm robotics, trustworthiness, safety, transparency, ethics, autonomous systems

I. INTRODUCTION

The main contribution of this paper is a novel framework for assurance of emergent behaviour for use in autonomous robotic swarms based on the AMLAS, SACE* and SOCA* guidance (* under consideration). We illustrate the framework using a public cloakroom case study.

II. BACKGROUND AND RELATED WORK

A. Background

1) Specification Challenges and Standards:

2) Robotic Swarms:

3) Case Study:
[Author Guidelines: Please use the cloakroom case study to illustrate the framework in Section III. If the examples in cloakroom case study are not sufficient, other swarm use cases listed below can be considered.]

a) Cloakroom: The case study describes a public cloakroom where swarm of robots assist customers looking to deposit their jackets at an event [1]. It describes cases where customers are depositing jackets, handing a jacket to a robot for storing, and retrieval of jackets back to the customer.

b) Other Swarm Use Cases:
Fault detection, diagnosis and recovery – Monitoring fires in a natural environment. Fault detection model shall be trained to high level of accuracy. Thresholds for fault tolerance shall be set appropriately such that misclassification of a fault is a rare event. An agent experiencing minor faults shall not be immediately removed, should the fault not impact the task at hand.
Social swarm – Brainstorming at an event. Humans follow robots which cluster based on input. Minimise blocking paths of other humans and agents. Maintain situational awareness of humans and agents in the environment. Before the task, provide a clear explanation of the steps of the activity. Clear guidance during the task. Provide information about how the swarm/robot works.
See research paper "Mutual shaping in swarm robotics: User studies in fire and rescue, storage organization, and bridge inspection" [2].

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B. Related Work

1) Assurance of Machine Learning in Autonomous Systems (AMLAS): Assurance of Machine Learning for use in Autonomous Systems (AMLAS) provides guidance on how to systematically integrate safety assurance into the development of machine learning components based on offline supervised learning [3]. AMLAS provides an explicit and structured safety case that the system is safe to operate in its intended context of use. AMLAS contains six stages, and the assurance activities are performed in parallel to the development of machine learning component. The process is iterative by design and feedback is used to update previous stages.

2) Safety Assurance of Autonomous Systems in Complex Environments (SACE): [4]

3) Societal Acceptability of Autonomous Systems (SOCA): [5], [6]

III. FRAMEWORK

A. Overview of Framework

B. Stage 1: EB Safety Assurance Scoping

[Lead: WP1]
[Author Guidelines: 900–1800 words / 1–2 pages (maximum);
Format/structure: Describe adapted AMLAS activities, inputs and outputs using cloakroom case study examples. Activities: 1, 2; Inputs: A, B, C, D, F; Outputs: E, G]
See Fig. 1

C. Stage 2: EB Safety Requirements Assurance

[Lead: WP1; Other: WP2, WP3]
[Author Guidelines: 1800–2700 words / 2–3 pages (maximum);
Format/structure: Describe adapted AMLAS activities, inputs and outputs using cloakroom case study examples.
WP1 = (Activities: 3, 4, 5; Inputs: E, I; Outputs: H, J, K))
WP2 = (List of Ethical Requirements and Description: 675 words / 0.75 page maximum)
WP3 = (List of Socio-Technical/Regulatory Requirements and Description: 675 words / 0.75 page maximum)]
See Fig. 2

D. Stage 3: Data Management

[Lead: WP5]
Author Guidelines: 900–1800 words / 1–2 pages (maximum);
Format/structure: Describe adapted AMLAS activities, inputs and outputs using cloakroom case study examples. Activities: 6, 7, 8; Inputs: H; Outputs: L0, L1, M, N, O, P, Q, S
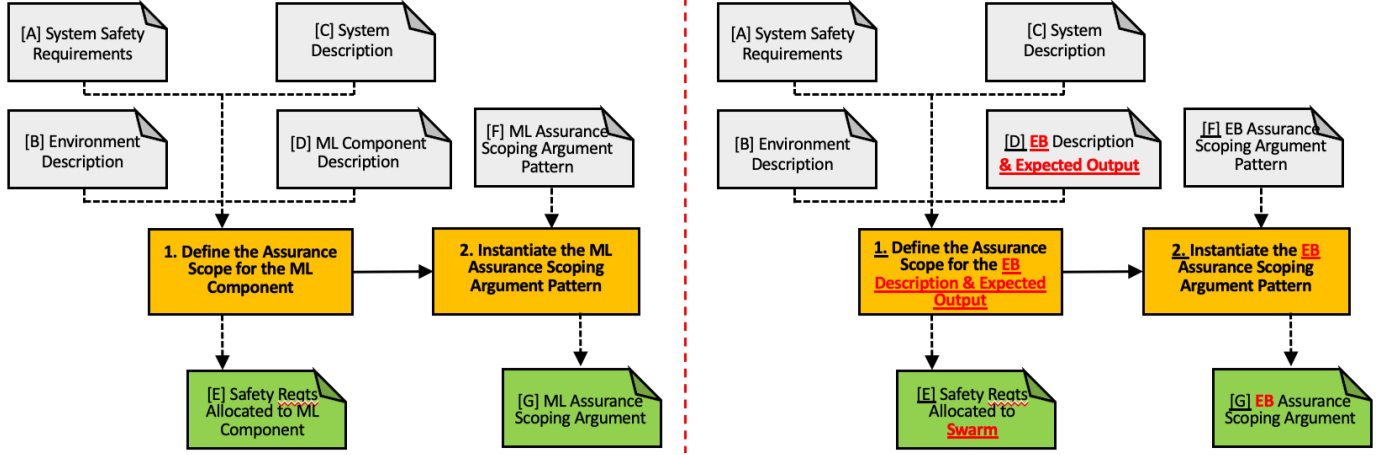See Fig. 3

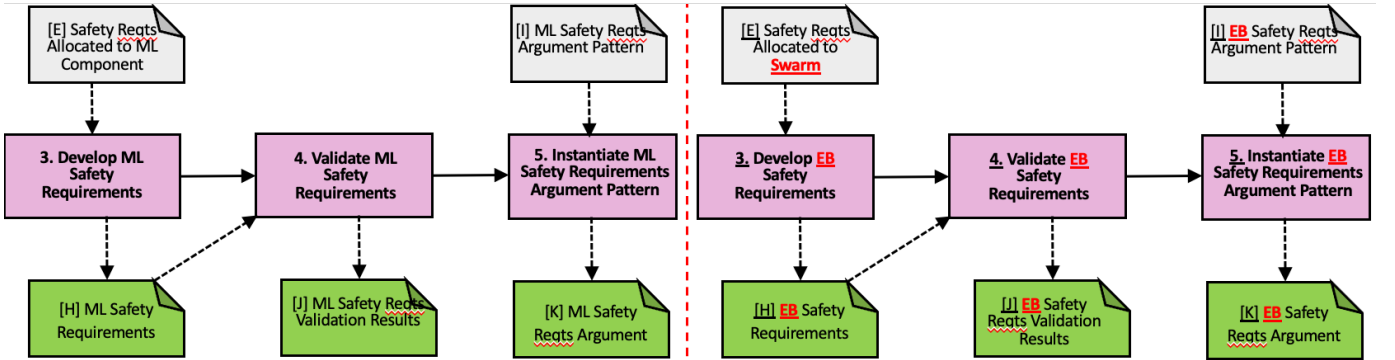Fig. 1. Adapted AMLAS emergent behaviour assurance scoping process (right).

Fig. 2. Adapted AMLAS emergent behaviour safety requirements assurance process (right).

E. Stage 4: Model Emergent Behaviour

[Lead: WP5]
Author Guidelines: 900–1800 words / 1–2 pages (maximum); Format/structure: Describe adapted AMLAS activities, inputs and outputs using cloakroom case study examples. Activities: 10, 11; Inputs: H, N, O; Outputs: Candidate EB Algorithm, U, V, X

See Fig. 4

F. Stage 5: Model Verification

[Lead: WP4]
Author Guidelines: 900–1800 words / 1–2 pages (maximum); Format/structure: Describe adapted AMLAS activities, inputs and outputs using cloakroom case study examples. Activities: 13; Inputs: H, P, V; Outputs: Z, AA
See Fig. 5 and Fig. 6.

- Test bench for swarms
- Probabilistic verification ideas
- Simulation-based testing
- Verifiability?

G. Stage 6: Model Deployment

[Leads: WP4 & WP5; Additional: WP3]
Author Guidelines: 900–1800 words / 1–2 pages (maximum);

Format/structure: Describe adapted AMLAS activities, inputs and outputs using cloakroom case study examples.
WP5 = (Activities: 15, Inputs: V, A, B, C, D, Outputs: DD),
WP4 = (Activities: 16, Inputs: EE, Outputs: FF),
WP3 = (Regulatory Considerations – 675 words / 0.75 page maximum)
See Fig. 7

IV. DISCUSSION AND CONCLUSIONS

ACKNOWLEDGMENTS

APPENDIX A. SUPPLEMENTARY MATERIAL

The supplementary material associated with this article can be found online at (https://www.).

REFERENCES

[1] S. Jones, E. Milner, M. Sooriyabandara, and S. Hauert, "Distributed situational awareness in robot swarms," *Advanced Intelligent Systems*, vol. 2, no. 11, p. 2000110, 2020. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1002/aisy.202000110

[2] D. Carrillo-Zapata, E. Milner, J. Hird, G. Tzoumas, P. J. Vardanega, M. Sooriyabandara, M. Giuliani, A. F. T. Winfield, and S. Hauert, "Mutual shaping in swarm robotics: User studies in fire and rescue, storage organization, and bridge inspection," *Frontiers Robotics AI*, vol. 7, p. 53, 2020.
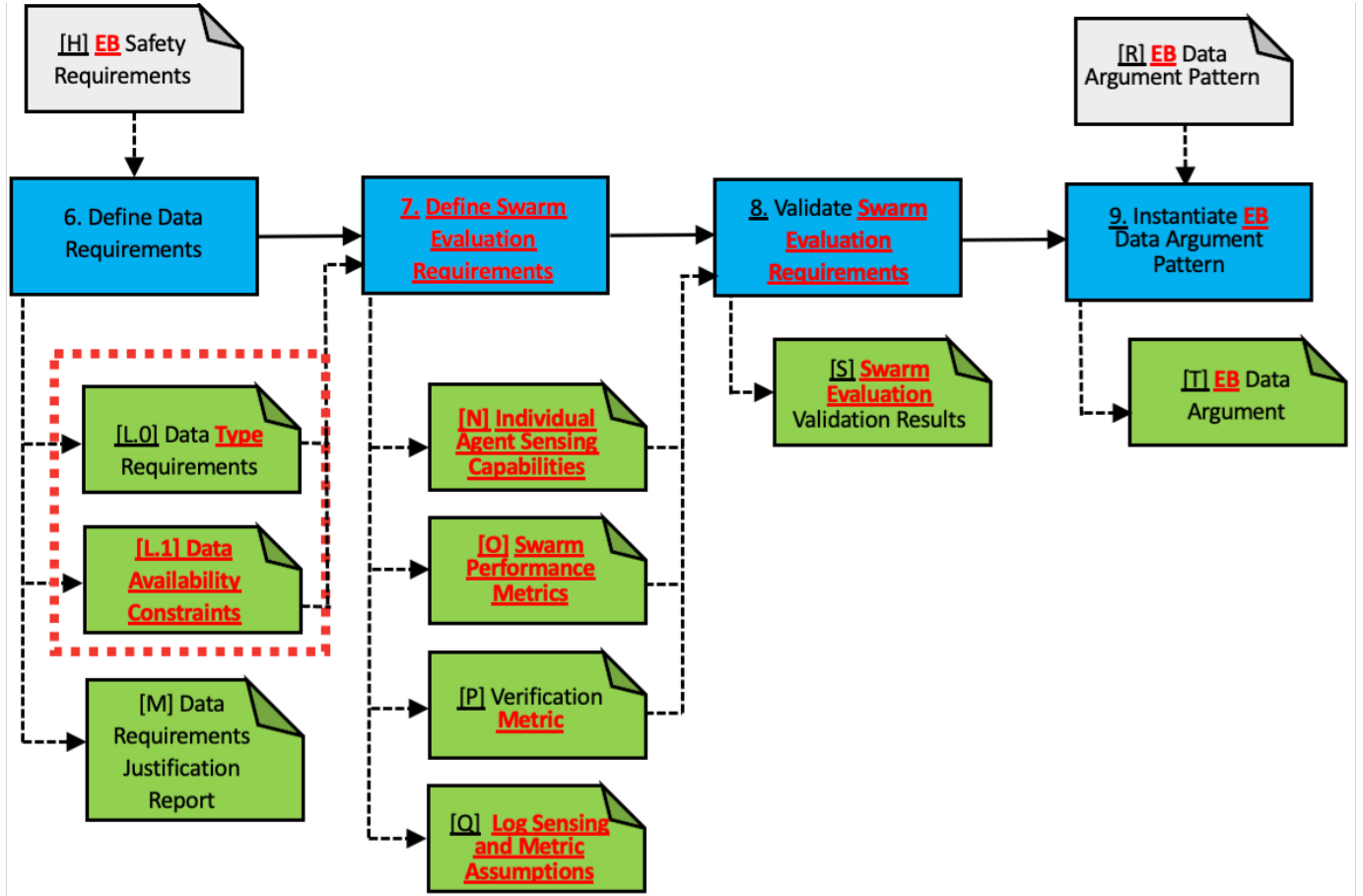
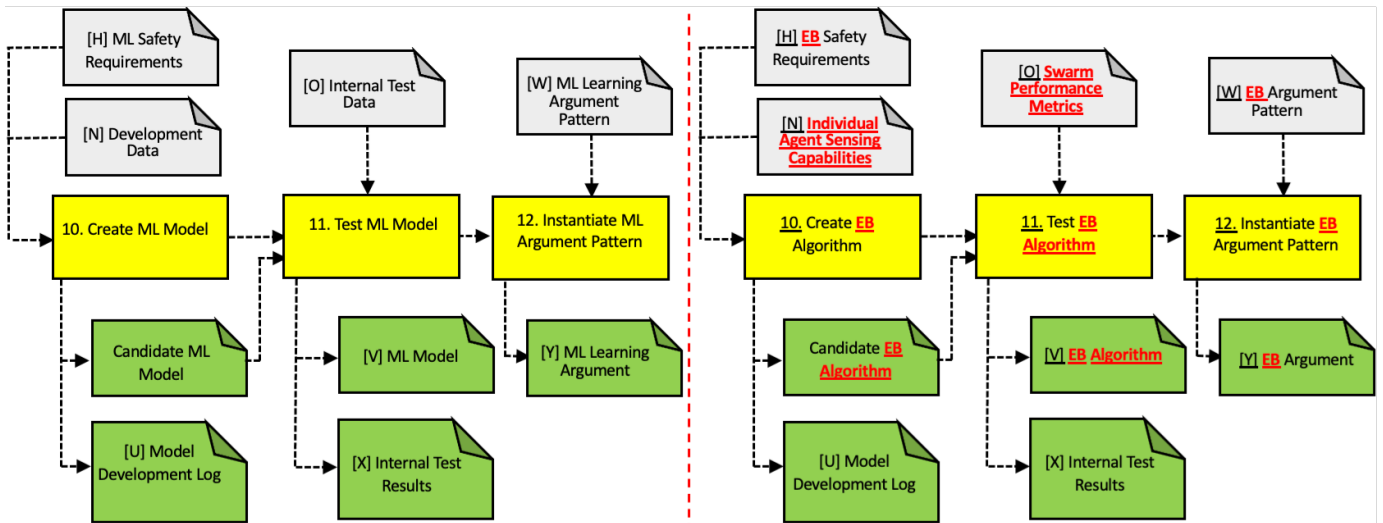Fig. 3. Adapted AMLAS data management process.

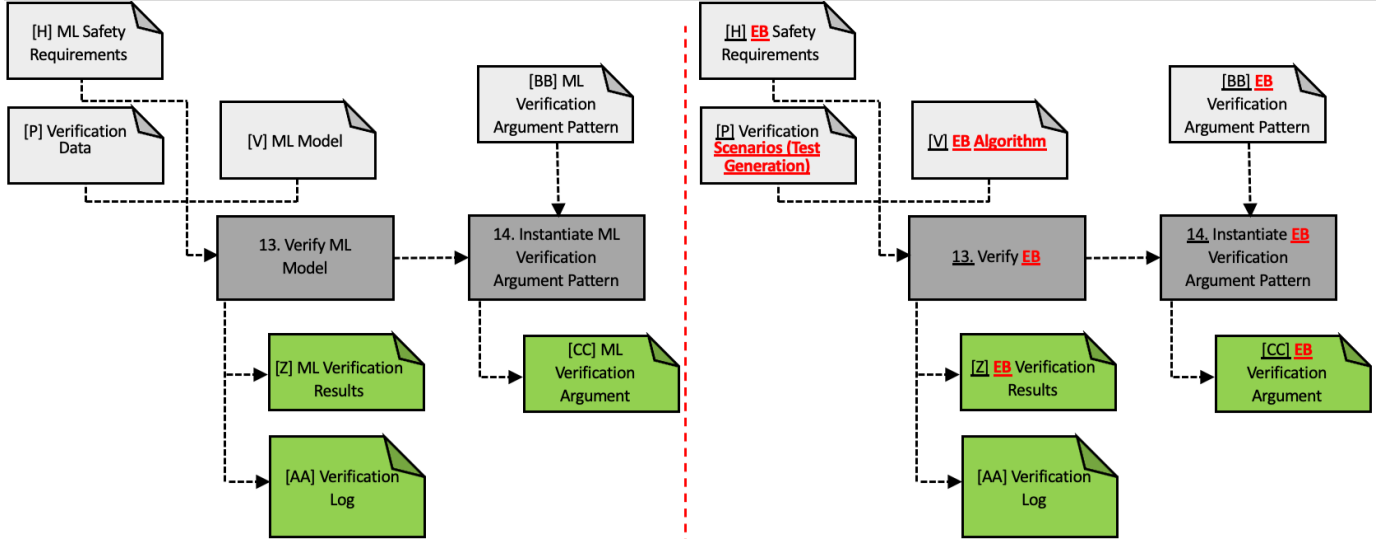Fig. 4. Adapted AMLAS model learning process (right).

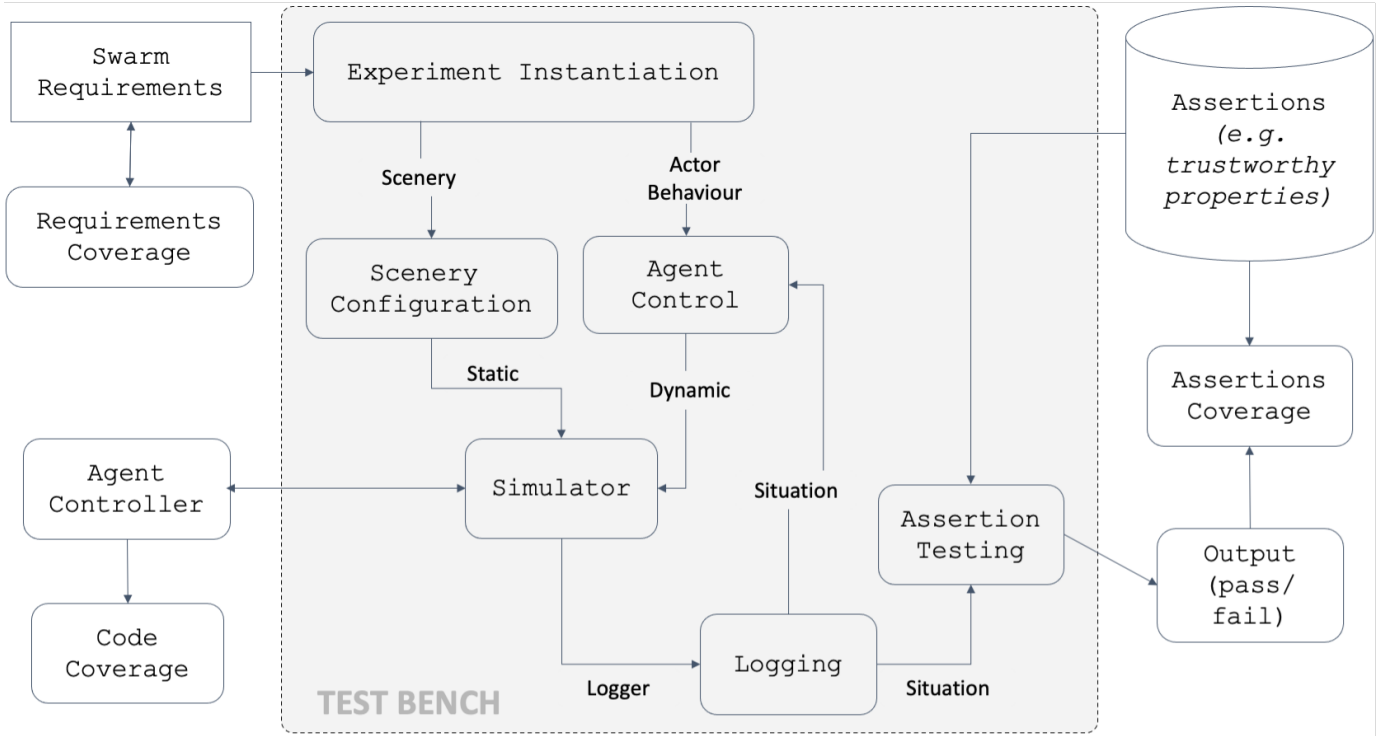Fig. 5. Adapted AMLAS verification assurance process (right).

Fig. 6. Adapted AMLAS verification assurance process: test bench.

[3] R. Hawkins, C. Paterson, C. Picardi, Y. Jia, R. Calinescu, and I. Habli, "Guidance on the assurance of machine learning in autonomous systems (amlas)," University of York, Guidance Version 1.1, Mar. 2021.

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[5] Z. Porter, I. Habli, and J. A. McDermid, "A principle-based ethical assurance argument for ai and autonomous systems," Mar. 2022.

[6] J. McDermid, Y. Jia, Z. Porter, and I. Habli, "Artificial intelligence explainability: the technical and ethical dimensions," *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences*, vol. 379, no. 2207, Aug. 2021.
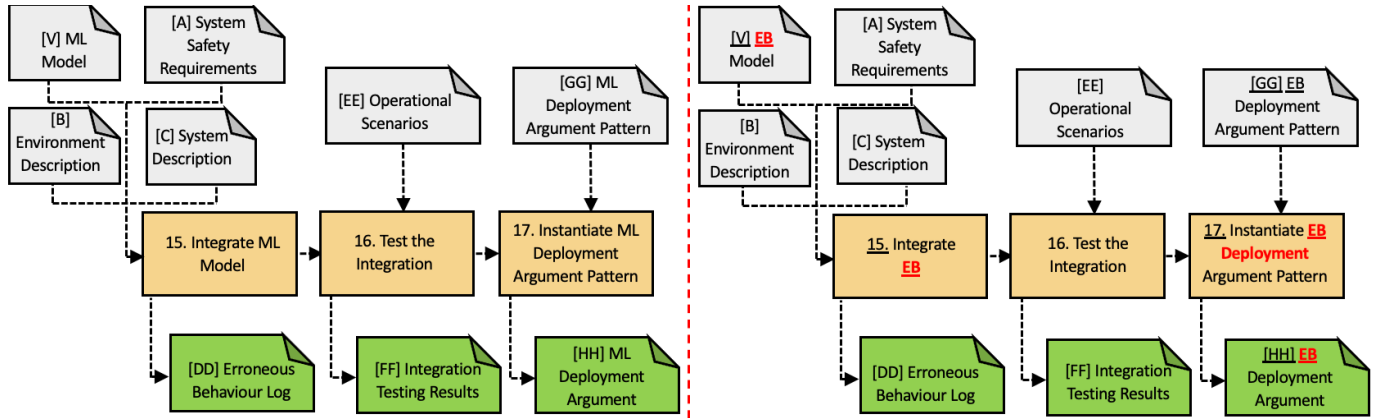
Fig. 7. Adapted AMLAS model deployment assurance process (right).