Model-Based Structured Requirements

McKenzy P. Johnson, Computer Engineering Student | Dr. Daniel R. Herber, Assistant Professor of Systems Engineering

Department of Systems Engineering, Colorado State University, Fort Collins, CO, USA

WALTER SCOTT, JR. COLLEGE OF ENGINEERING
COLORADO STATE UNIVERSITY

Purpose

- To demonstrate the advantages of transitioning from text-based documentation of system requirements to an architectural model.
- An architectural/abstract model:
  - describes relationships between the system's structure, behavior, and rules;
  - defines systems engineering (SE) activities, such as test processes.
- Evidence already supports the use of model-based structured requirements (MBSR) in enabling more efficient system development. [1]
- The goal of this project has been to create an example with a UAV model [2] using MBSR to further demonstrate its effectiveness and quality.

Method

- This example was created through the Cameo Systems Modeler tool that uses the Systems Modeling Language (SysML), an object-oriented language enabling component interaction within diagrams and other structures. [3]
- The structure used for requirements in this example is:

  The [WHO] shall [WHAT] [HOW WELL] under [CONDITION]. [4]

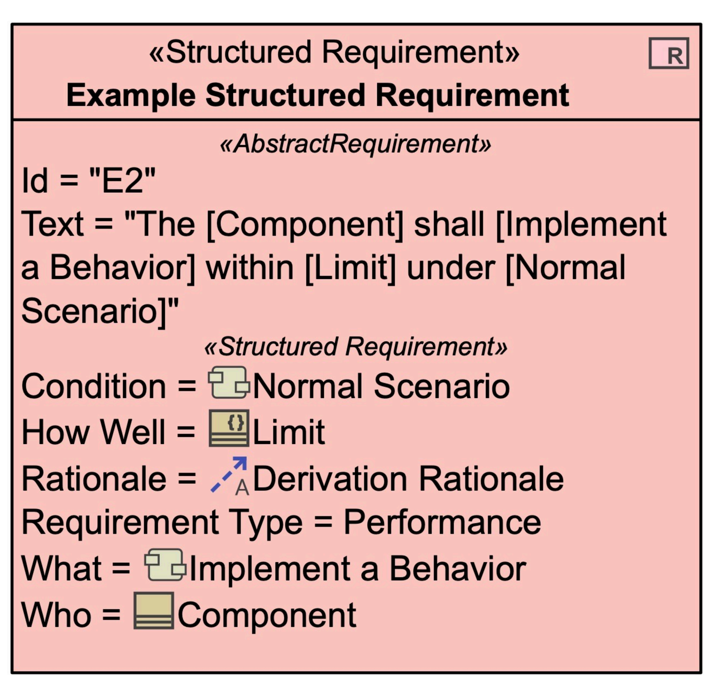
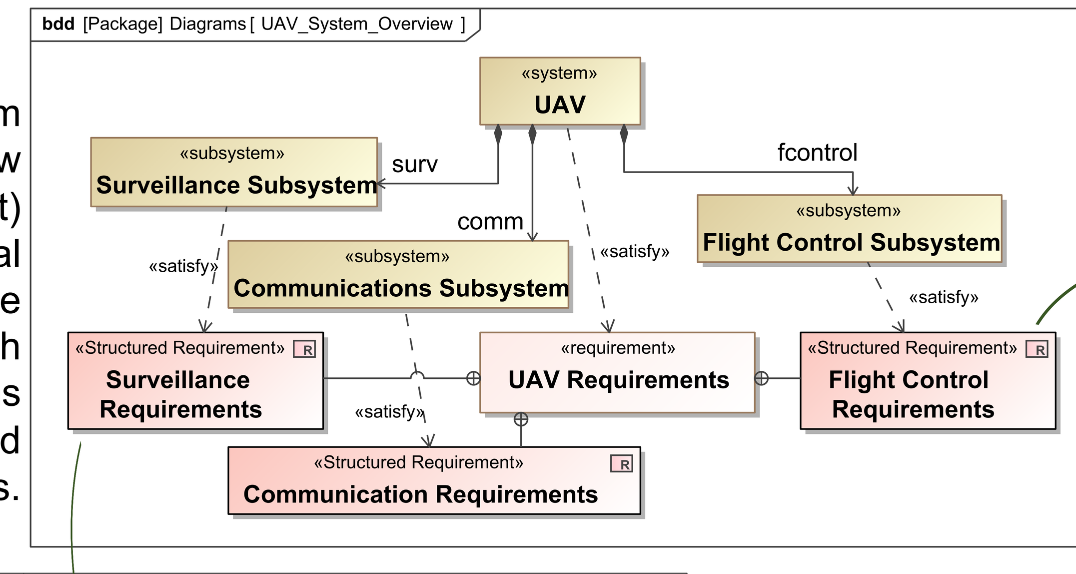


Figure 1: An example of a structured requirement implementing the who-what-how well-condition format. [5]

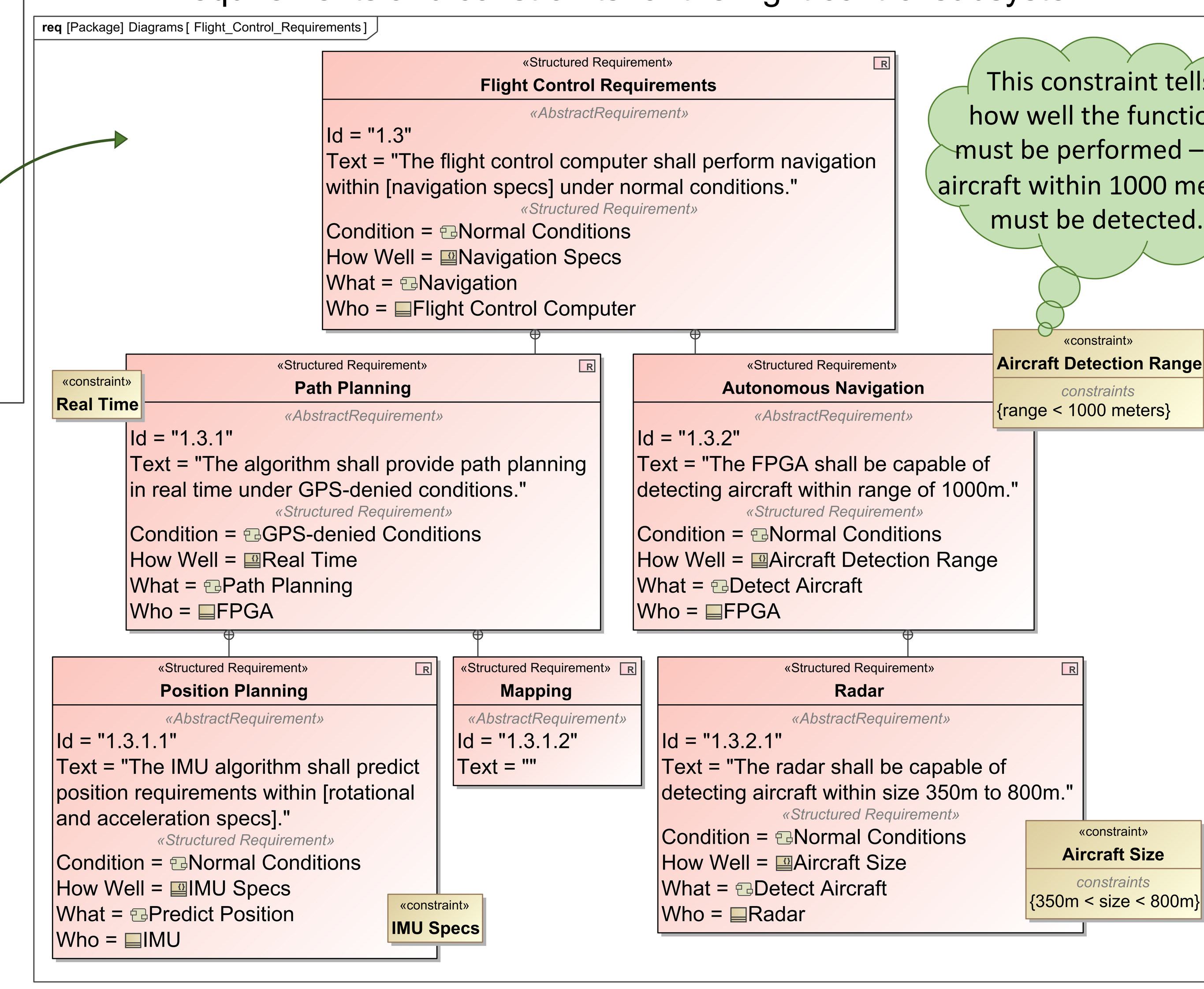
[WHO] defines the subject - a component that provides a function to the system.
[WHAT] refers to the specified function that is required by the system.
[HOW WELL] specifies the constraints and limits of the performance or design of the function.
[CONDITION] describes the environment or scenario under which the function must perform.

Results

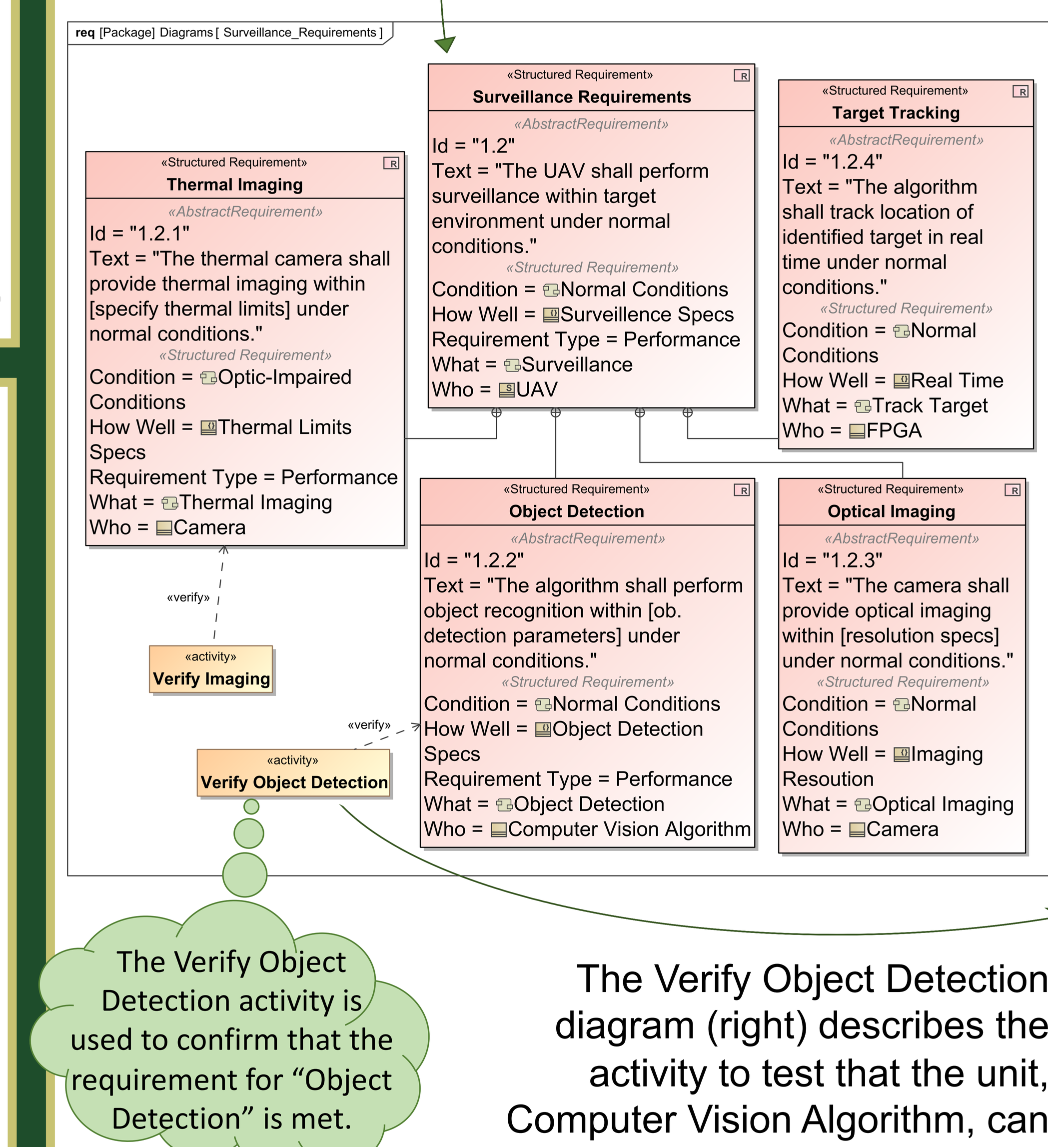
The UAV System Overview diagram (right) displays a partial structure of the UAV system with three subsystems and their related requirements.



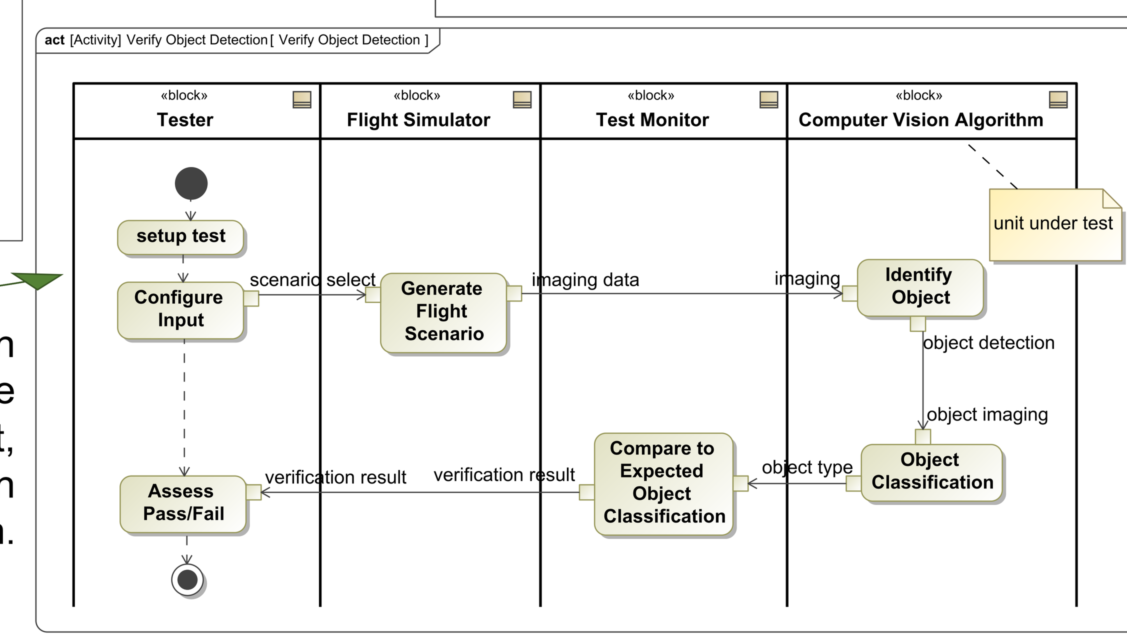
The Flight Control Requirements diagram (below) displays the requirements and constraints for the flight control subsystem.



The Surveillance Requirements diagram (left) breaks down some of the essential behaviors for targeted observation.



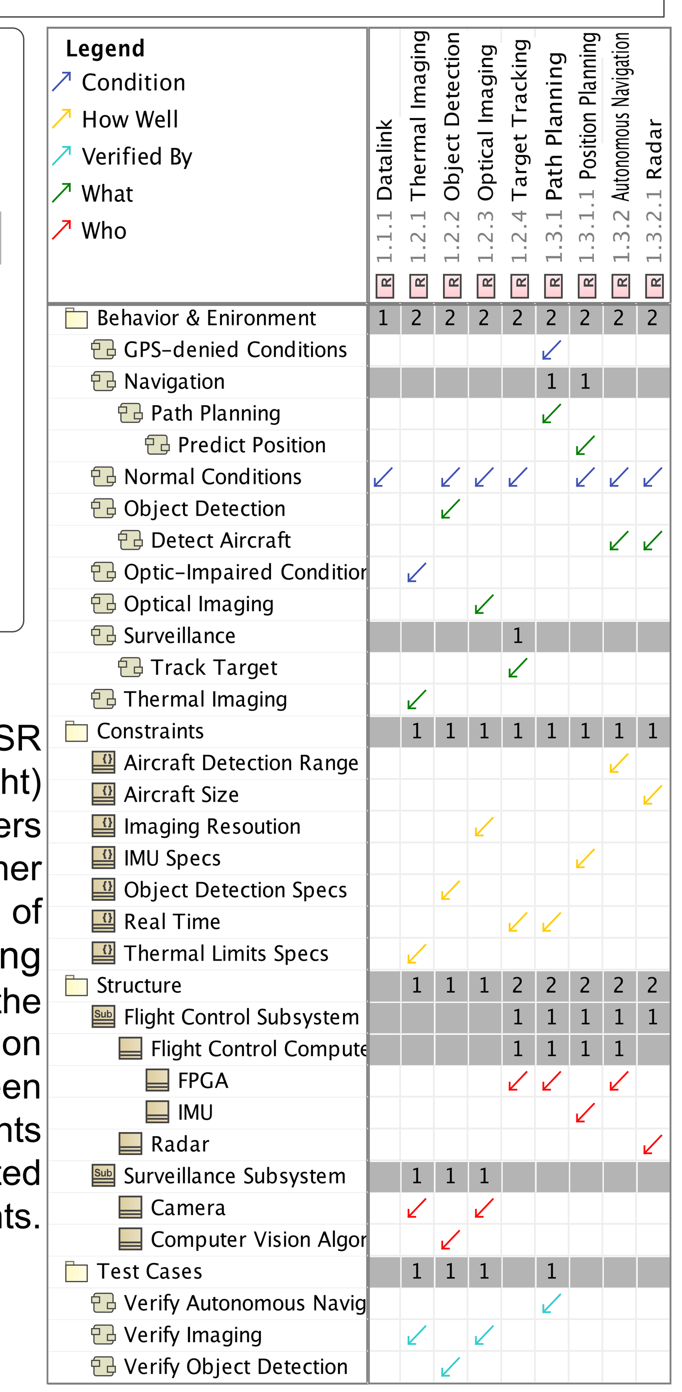
The Verify Object Detection diagram (right) describes the activity to test that the unit, Computer Vision Algorithm, can perform object detection.



The Requirements Table (below) is a more complete overview of the model's relationships.

#	Name	Text	Who	Condition	What	How Well	Verified By
1	1 UAV Requirements	UAV Requirement Specification					
2	1.1 Communication Requirements	The communication subsystem shall provide communication within UAS under normal conditions.	Communications Sub...	Normal Conditions	Communication		
3	1.1.1 Datalink	The datalink shall provide full duplex communication with the GCS under normal conditions.		Normal Conditions			
4	1.2 Surveillance Requirements	The UAV shall perform surveillance within target environment under normal conditions.	UAV	Normal Conditions	Surveillance	Surveillence Specs	
5	1.2.1 Thermal Imaging	The thermal camera shall provide thermal imaging within [specify thermal limits] under normal conditions.	Camera	Optic-Impaired Conditions	Thermal Imaging	Thermal Limits S...	Verify Imaging
6	1.2.2 Object Detection	The algorithm shall perform object recognition within [ob. detection parameters] under normal conditions.	Computer Vision Alg...	Normal Conditions	Object Detection	Object Detection...	Verify Object Detection
7	1.2.3 Optical Imaging	The camera shall provide optical imaging within [resolution specs] under normal conditions.	Camera	Normal Conditions	Optical Imaging	Imaging Resoution	Verify Imaging
8	1.2.4 Target Tracking	The algorithm shall track location of identified target in real time under normal conditions.	FPGA	Normal Conditions	Track Target	Real Time	
9	1.3 Flight Control Requirements	The flight control computer shall perform navigation within [navigation specs] under normal conditions.	Flight Control Comp...	Normal Conditions	Navigation	Navigation Specs	
10	1.3.1 Path Planning	The algorithm shall provide path planning in real time under GPS-denied conditions.	FPGA	GPS-denied Conditions	Path Planning	Real Time	Verify Autonomous Navigation
11	1.3.1.1 Position Planning	The IMU algorithm shall predict position requirements within [rotational and acceleration specs].	IMU	Normal Conditions	Predict Position	IMU Specs	
12	1.3.1.2 Mapping						
13	1.3.2 Autonomous Navigation	The FPGA shall be capable of detecting aircraft within range of 1000m.	FPGA	Normal Conditions	Detect Aircraft	Aircraft Detectio...	
14	1.3.2.1 Radar	The radar shall be capable of detecting aircraft within size 350m to 800m.	Radar	Normal Conditions	Detect Aircraft	Aircraft Size	

The MBSR Matrix (right) offers another method of displaying the connection between requirements and related components.



Discussion

- This UAV example worked on in this project is not a complete model.
  - Specific constraints or verification means were intentionally left blank due to a lack of pertinent information.
  - Some spaces were filled in with a non-specific component that should be precisely defined.
- An important function of MBSR is the ability to examine completeness and ensure the knowledgeable person(s) define necessary components and behaviors.

Next Steps

- This example can be expanded further.
  - Many more requirements can be included.
  - More diagrams can be used to describe components.
  - Additional subsystems need to be modeled.
  - More test diagrams are needed to verify current and future requirements.
- The modeling tool also offers state machine, sequence, and use case diagrams, to name a few.
- Beyond this UAV model, other examples need to be created so to demonstrate the concept of MSBR on more systems.

Conclusions

- This UAV model demonstrates the advantages of an architectural model (which can be compared to its derived text description [2])… these benefits include:
  - clearly defined requirements,
  - understandable component relations,
  - clear activity diagrams modeling test processes,
  - more diagrams to dynamically describe behaviors of the system.
- "The [WHO] shall [WHAT] [HOW WELL] under [CONDITION]" text statement is a clear way to structure requirements.

How do you plan to apply what you have learned?

I plan to continue working with Dr. Herber to develop examples of MBSR. Modeling UAV subsystems in this project has given me skills to dynamically organize and understand complex engineering systems. I can utilize these skills in my future work as a Computer Engineer.

What benefits did you get from your SURE experience?

The SURE experience has enabled me to learn new skills and educate myself on a topic of my own interest (UAVs). I learned some basics of SysML, in addition to the opportunity to experience systems modeling with a tool I would not have otherwise had access to. Through the creation of this UAV example, I developed a new way to look at engineering systems through the lens of structured requirements. This perspective will be extremely beneficial in the future and help me to design systems that are complete and organized.

References

[1] T. Huldt and I. Stenius, "State-of-practice survey of model-based systems engineering," *Syst. Eng.*, vol. 22, no. 2, pp. 134–145, Sep. 2018, doi: 10.1002/sys.21466
[2] Ahmed, F. and Jenihhin, M. Unmanned Aerial Vehicle Computing Platforms. Encyclopedia. https://encyclopedia.pub/entry/31724 (accessed on 18 April 2023).
[3] S. Friedenthal, A. Moore, and R. Steiner, *A Practical Guide to SysML*, 3rd ed. Elsevier, 2015, doi: 10.1016/C2013-0-14457-1.
[4] D. R. Herber, J. B. Narsinghani, K. Eftekhari-Shahroudi. '*Model-based structured requirements in SysML*.' In IEEE 2022 International Systems Conference, Apr 2022. 10.1109/SysCon53536.2022.9773813
[5] Model-based structured requirements. [Online]. Available: https: //github.com/danielrherber/model- based- structured-requirements.

Thank you to the Suzanne and Walter Scott Foundation, The Filsinger Family, and Contributors to the Dean's Innovation fund for making the SURE program possible. Thank you also to the CSU Provost Office for their very generous funding of this program as part of the Student Success Initiative, highlighting CSU's commitment to student success.