

Usage of AI to Generate and Decompose Requirements

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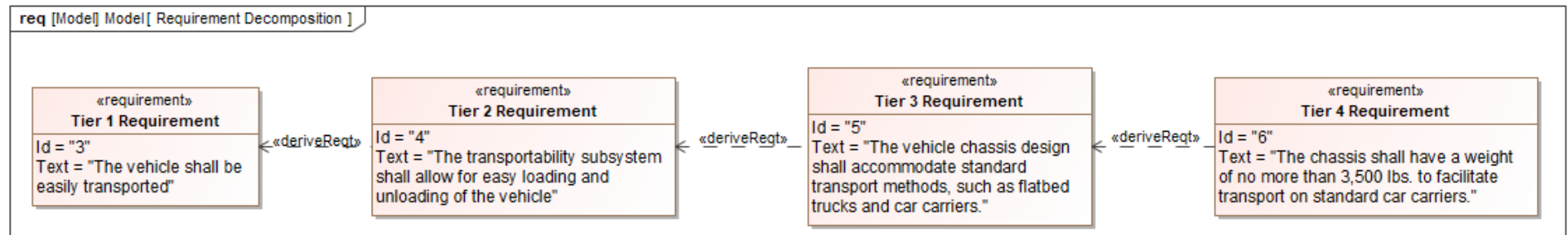
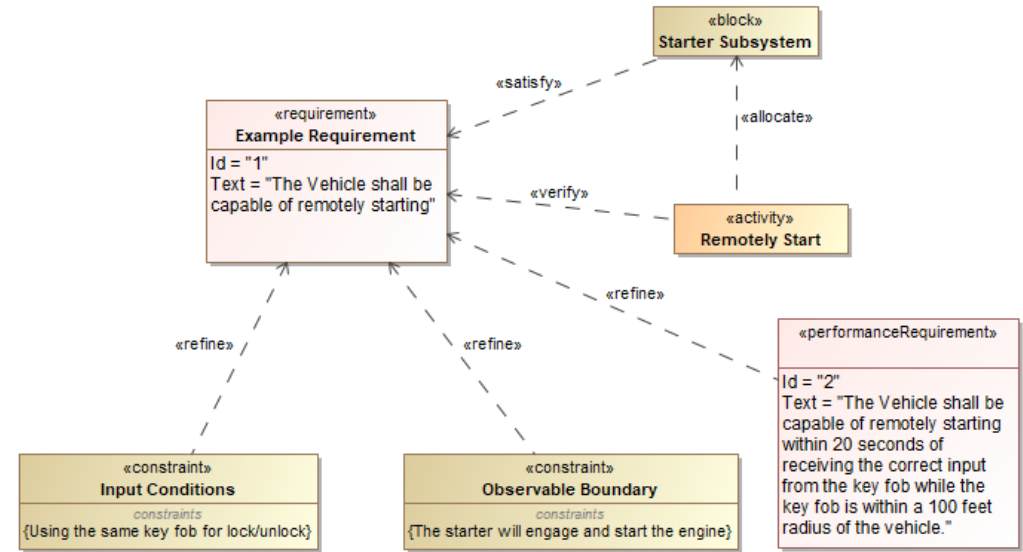
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Purpose

- **Poor requirements are a constant plague on programs both commercial and defense.**
- **The purpose of this project was to use AI seeded with a structured expression to quickly decompose from Tier 1 to Tier 4 to evaluate the effectiveness of the decomposition.**
- **Effectiveness is measured by comparing AI requirements to the INCOSE requirement rubric and alignment to the structured expression.**
- **Disclaimer: This is not about the ethics or security of AI, merely using its language processing power to decompose a prompt**

Method

- ChatGPT was used in this project.
 - Specifically, the free 4o model
- By instructing the AI to utilize the below structured expression, it was able to generate requirements from Tier 1 to Tier 4.
 - The structured expression used for generating requirements was:
 - “The [Agent] shall [execute activity] [under input conditions] [with performance characteristics] [observable at specific boundary]”
- The AI was not instructed to parse between threshold and objective levels of performance or to parse between true requirements and customer desires, only to decompose the statements into a workable framework.



Method (cont.)

- **Using this method and structure, a vague requirement can be made into the frame of a serviceable one**
 - Lower tier requirements were derived from the higher tier requirements
 - These relationships can be realized in a model

#	△ Name	Text
1	<input type="checkbox"/> 3 Tier 1 Requirement	The vehicle shall be easily transported
2	<input type="checkbox"/> 4 Tier 2 Requirement	The transportability subsystem shall allow for easy loading and unloading of the vehicle
3	<input type="checkbox"/> 5 Tier 3 Requirement	The vehicle chassis design shall accommodate standard transport methods, such as flatbed trucks and car carriers.
4	<input type="checkbox"/> 6 Tier 4 Requirement	The chassis shall have a weight of no more than 3,500 lbs. to facilitate transport on standard car carriers.

Requirement Set for Input

- **We provided the AI with a list of high-level customer desires for a consumer grade vehicle.**
 - This was chosen as a complex enough system to necessitate the generation of requirements that would challenge an engineer and thus be useful to apply AI to.
- **Set of 18 requirements input ranging from specific environmental requirements to vague functional requirements.**
 - Intentionally input requirements that were written poorly to simulate real world conditions

Requirements Input



Criteria

Scope (optional): Filter: Context (optional):

#	△ Name	Text
1	<input type="checkbox"/> 1 Remote Start	The Vehicle shall be capable of remotely starting
2	<input type="checkbox"/> 2 Speed	We want a vehicle that is capable of going 100 miles per hour.
3	<input type="checkbox"/> 3 Lock with Fob	The vehicle shall be lockable with a key fob.
4	<input type="checkbox"/> 4 Cyber Security	The system shall prevent incursion via cyber security measures.
5	<input type="checkbox"/> 5 Cargo Transport	The vehicle shall be easily transported
6	<input type="checkbox"/> 6 Automatic Parking	The vehicle should be able to self park
7	<input type="checkbox"/> 7 Remote Starting	The system should be able to be remotely started
8	<input type="checkbox"/> 8 Adaptive Cruise	The vehicle shall include adaptive cruise control
9	<input type="checkbox"/> 9 Crash Testing	The vehicle shall be crash tested for occupant safety
10	<input type="checkbox"/> 10 Avoid Collision	The vehicle shall be capable of collision avoidance
11	<input type="checkbox"/> 11 Hardware Standard Compliance	The vehicle fasteners shall comply with all current standards
12	<input type="checkbox"/> 12 Adjustments	The vehicle shall have adjustable seats and steering column
13	<input type="checkbox"/> 13 Alarm System	The vehicle shall sound an alarm when unauthorized physical entry has been attempted
14	<input type="checkbox"/> 14 Light Adjustment	The vehicle shall automatically dim headlights when appropriate
15	<input type="checkbox"/> 15 Emergency Braking	The vehicle shall be able to stop safely in the event of brake failure
16	<input type="checkbox"/> 16 Automotive Industrial Compliance	The vehicle shall comply with current automotive industry manufacturing and safety standards and regulations
17	<input type="checkbox"/> 17 Cabin Space	The vehicle shall have interior dimensions suitable below and above average male and female proportions
18	<input type="checkbox"/> 18 Crash Safety Measures	The vehicle airbags shall deploy to protect the occupant in the event of a crash or wreck

Requirements Output

- **With an input of 18 Tier 1 Requirements, ChatGPT was able to parse them into**
 - 33 Tier 2 Requirements
 - 53 Tier 3 Requirements
 - 76 Tier 4 Requirements
- **These were subject to grading according to the INCOSE requirement rubric**

Grading Rubric

- The [INCOSE Guide to Writing Requirements v4](#) was used by the SME to grade the AI output along with each section of the structured expression

	Requirement	1	3	5	7	10
INCOSE Writing Requirements v4	Necessary	No	N/A	Partial	N/A	Yes
	Appropriate	No	N/A	Partial	N/A	Yes
	Singular	No	N/A	Partial	N/A	Yes
	Correct	No	N/A	Partial	N/A	Yes
	Conforming	No	N/A	Partial	N/A	Yes
	Unambiguous	No	N/A	Partial	N/A	Yes
	Complete	No	N/A	Partial	N/A	Yes
	Feasible	No	N/A	Partial	N/A	Yes
	Verifiable	No	N/A	Partial	N/A	Yes
Structured Expression	Agent	Missing	Minimally Identified but severely lacking in data	Identified with incomplete or TBD data	Identified with mostly correct and complete data	Complete with no identified improvements
	Function	Missing	Minimally Identified but severely lacking in data	Identified with incomplete or TBD data	Identified with mostly correct and complete data	Complete with no identified improvements
	Input	Missing	Minimally Identified but severely lacking in data	Identified with incomplete or TBD data	Identified with mostly correct and complete data	Complete with no identified improvements
	Performance	Missing	Minimally Identified but severely lacking in data	Identified with incomplete or TBD data	Identified with mostly correct and complete data	Complete with no identified improvements
	Boundary	Missing	Minimally Identified but severely lacking in data	Identified with incomplete or TBD data	Identified with mostly correct and complete data	Complete with no identified improvements

Requirements Output – Raw Data



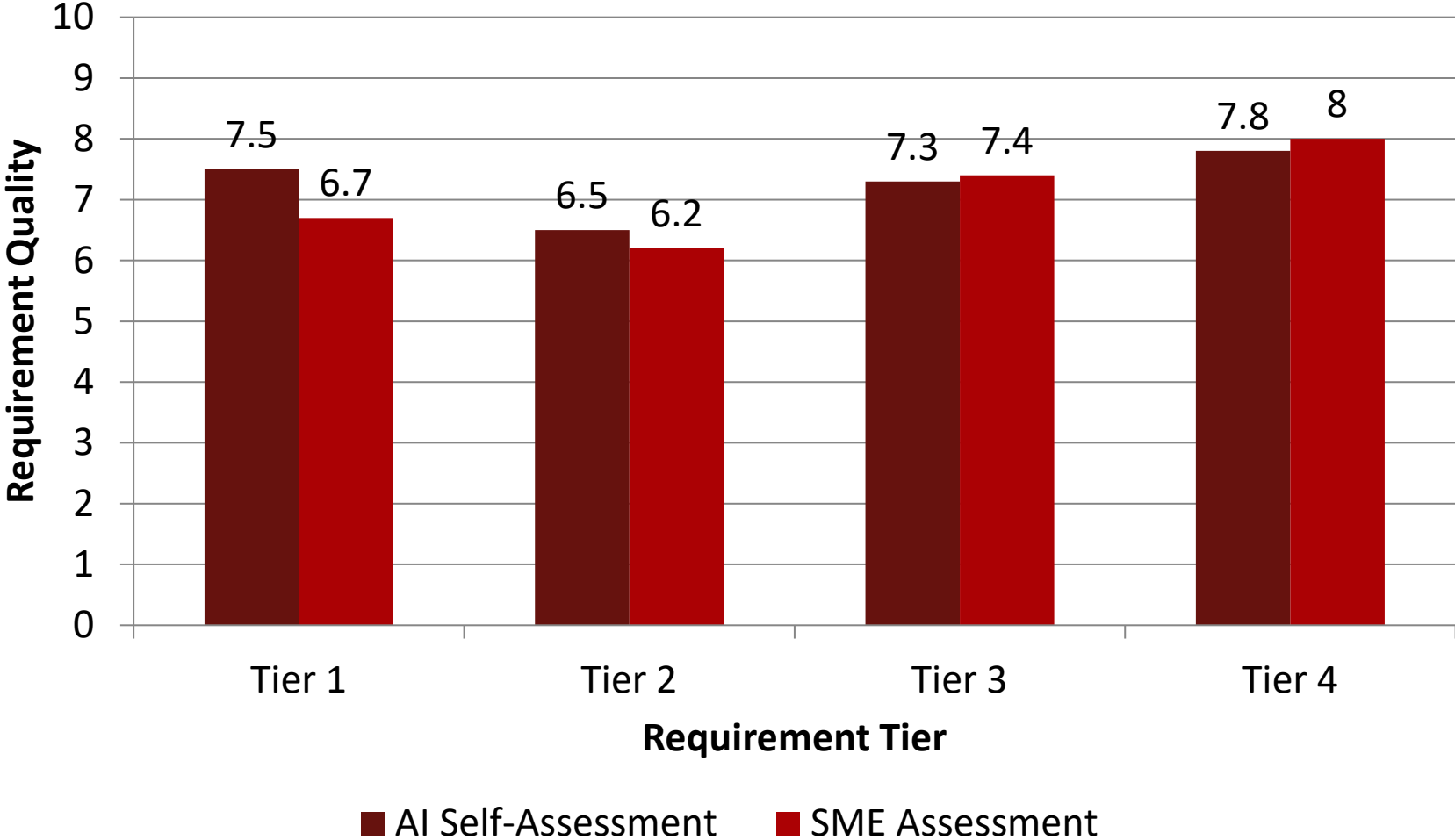
AI Assessment

Requirement	Tier 1	Tier 2	Tier 3	Tier 4
1. Vehicle Speed	7	7.5	8	8
2. Weather Conditions	7.5	7.5	7.5	8.5
3. Locking System	7	7	7	8
4. Cybersecurity	7	5.5	8	7
5. Interior Dimensions	8	5.5	6.5	8
6. Adjustable Seats & Steering	8.5	7	8.5	8
7. Alarm System	6.5	6	6.5	7
8. Self-Parking Capability	7.5	6	6	7.5
9. Remote Start	7.5	7	6	8
10. Automatic Headlight Dimming	7.5	6	8.5	7.5
11. Adaptive Cruise Control	8.5	7	7	7.5
12. Collision Avoidance	7	6	7	7.5
13. Safe Stop in Brake Failure	8	6	7	8.5
14. Transportability	7	7.5	7	8
15. Compliance with Standards	7.5	6	8	8
16. Fastener Standards	8	6.5	6	8
17. Airbag Deployment	8	6	8.5	7.5
18. Crash Testing	7	7	8	8
Average	7.5	6.5	7.3	7.8

SME Assessment

Requirement	Tier 1	Tier 2	Tier 3	Tier 4
1. Vehicle Speed	7	6	8	8
2. Weather Conditions	6.5	6.5	7.5	8.5
3. Locking System	7	7	7	8
4. Cybersecurity	7	5.5	8	8
5. Interior Dimensions	5	5.5	7.5	8
6. Adjustable Seats & Steering	5.5	7	8.5	8.5
7. Alarm System	6.5	6	7.5	7
8. Self-Parking Capability	7.5	6	6	7.5
9. Remote Start	6.5	7	6	8
10. Automatic Headlight Dimming	7.5	6	8.5	7.5
11. Adaptive Cruise Control	6.5	7	7	8.5
12. Collision Avoidance	7	6	7	8.5
13. Safe Stop in Brake Failure	8	6	7	8.5
14. Transportability	7	7.5	7	8
15. Compliance with Standards	7.5	6	8	8
16. Fastener Standards	6	5.5	6	8
17. Airbag Deployment	6	6	8.5	7.5
18. Crash Testing	6.5	5	8	8
Average	6.7	6.2	7.4	8.0

Requirements Quality



Requirements Output - Summary

- Chat GPT's requirements from Tier 1 to Tier 4 were parsed from the human input Tier 0
- Grading variance between tiers 1 and 2 identify key grading discrepancy between SME and AI

Requirement Level	Tier 1	Tier 2	Tier 3	Tier 4
Variance between AI & SME Grading	-0.8	-0.3	+0.2	+0.2

- While the overall scores came out close there were notable differences in grading for Input Conditions, Performance Metrics, and Boundary.

AI Strengths

- identification of complex math relationships
- ensuring complete decompositions

SME Strengths

- Identification of input parameters
- Boundary conditions
- Performance characteristics

Requirement Decomposition Analysis

- **The AI was fed a requirement on overall speed and was able to decompose that need:**
 - Into horsepower the engine would need to generate
 - A drag coefficient for the aerodynamic design
 - A flow rate for coolant to maintain that speed
 - A fuel flow rate and more variables
- **This highlights the AI's ability to catch all the various mathematical variables necessary where a human may miss some due to being focused on good requirements and overall systems design.**

Requirements Decomposition Analysis Cont.

- **AI scored lower at the Tier 2 requirements level**
 - Missing clearly defined, quantifiable objectives
 - Data provided is incomplete
 - Incorrect assumptions (i.e. stating that a fastener is a subsystem)
- **These misses show where SME involvement brings the most value**
 - SMEs understand fully the system and the system context
 - AI only understands the language processing

Summary & Final Takeaways

- **Since requirements decomposition is an area where many programs consistently struggle evaluating the quality of the written requirements should be performed.**
 - Requirements SMEs partnered with AI could mitigate the risk of having poorly written requirements define a systems architecture.
 - SME knowledge is critical to providing complete and correct requirements at the Tier 1 and Tier 2 level, where system context is being shaped.
 - AI has been proven to effectively evaluate the written requirements at the Tier 3 and Tier 4 level, where quantifiable objectives are captured.
- **Leveraging the proposed structured framework for requirements development, AI can quickly and effectively develop tier 3 and tier 4 requirements, allowing SMEs to focus their efforts on other high value areas.**
- **Further development opportunities are taking these requirements and integrate them into an Architecture Model for verification/traceability and improving the AI interaction to identify threshold vs. objective requirements.**

Questions?