INCOSE Michigan Chapter

Monthly Newsletter

September 2026

In This Issue

President's Message

I hope that you had a pleasant August; it is hard to believe that summer is almost over. Our August technical meeting on AI-powered SysML v2 with SysModeler.ai was postponed until August 25th. Thanks again to Md Tawhid Bin Waez, PhD for his presentation and demonstration.

Nathan and I attended *Fuel for Thought: Route 66 at 100* at Stahls Motors & Music Experience; we learned a lot about the road and the ongoing Great Race events that use it (a Stahls team won the 2026 Hemmings Great Race). Although I have no desire to drive for hours guided by a stopwatch, I do think that traveling some section of Route 66 is now on my “bucket list.” If nothing else, I will make a point to seek out some of the semi-obscure roadside attractions still in operation to enjoy that slice of Americana. The most pleasant surprise for me was seeing (and hearing) some of the music machines in action (including the Wurlitzer Theatre Pipe Organ).

September promises to be busy, with a wide variety of INCOSE Michigan and partner events. See the calendar below…and I do want to call your attention to these chapter events: First, Karl Selewski will be hosting a certification information session on September 15th. Second, we will be visiting the MRover team (which competes in the Mars Society University Rover Challenge) at the University of Michigan later that day. MRover is the first-ever winner of the INCOSE Foundation Systems Engineering Excellence Award and we will be presenting a trophy on behalf of the Foundation as we tour their facility. We will also have a Systems Soirée immediately afterward at Relish in the Kensington Hotel. Please join us and encourage these students (and enjoy some top-tier barbeque).

It is also the Detroit Month of Design and we have an Engineering Expedition to see *SCORE: Sports by Design* at the Metropolitan Museum of Design Detroit on September 12th.

I am working to schedule a memorable virtual session with a one-of-a-kind artist; stay tuned for details!

Finally, this month’s Historical Corner is a triple feature: Automotive safety, Viking 2, and Gemini XI. I hope you find the historical lessons to be interesting and useful.

We will be sending out a poll at the end of the month to solicit your input on our end-of-year social. Please respond!

Michael J. Vinarcik, ESEP-Acq, P.E., FESD

President

Nathan Vinarcik (Secretary), Lightning McQueen, and Michael Vinarcik (President)

A Mills Deluxe Violano-Virtuoso

Chapter News

We added “Awards” to the INCOSE Michigan website (under “About”) and a Resources menu (currently includes thoughts about the University Rover Challenge).

Upcoming Events Calendar

Date	Event	Organization
September 2	Webinar 204: Agility as Resilient Emergent Behavior	INCOSE
September 10	AISE Café: MBSE Around the World — What Works, What Fails, and Why	AISE (INCOSE Italia)
September 12	Engineering Expedition: SCORE: Sports by Design (Metropolitan Museum of Design Detroit)	INCOSE Michigan Chapter
September 15	INCOSE Certification Information Session	INCOSE Michigan Chapter
September 15	MRover (University Rover Challenge Team), Ann Arbor + Systems Soirée (Relish Restaurant)	INCOSE Michigan Chapter
September 16	AVL Tour and Open House	SAE Detroit Section
September 16	Webinar 205: Product Line Engineering in Aerospace & Defense	INCOSE
September 16	Systems Engineering of the James Webb Space Telescope	INCOSE Enchantment Chapter
September 18	Transforming Project Management in an AI World	PMI Great Lakes
September 25	Dossin After Dark	Dossin Great Lakes Museum
October 3	Sidequest Social: An Idiot's Guide to Wine	INCOSE Michigan Chapter
October 6	SysML v2.0 Requirements (Lockheed Martin)	INCOSE Michigan Chapter
October 21-24	PMI Global Summit 2026 “Built to Move”	PMI
October 29	Engineers Get Hired Job Fair	Engineering Society of Detroit
November TBD	Virtual Meeting (TBD)	INCOSE Michigan Chapter
December TBD	F2F Technical / Social Event	INCOSE Michigan Chapter

Upcoming Chapter Events

Engineering Expedition: SCORE: Sports by Design

Saturday, September 12, 2026 · Metropolitan Museum of Design Detroit

Date: Saturday, September 12, 2026, 12:00 - 3:00 PM EDT

Location: Lunch: Mudgie's Deli and Wine Shop, 1413 Brooklyn St, Detroit (Corktown)
Metropolitan Museum of Design Detroit, 905 Henry Street, 3rd Floor, Detroit, Michigan 48201

Cost: Free (lunch on your own)

Detroit is the only UNESCO City of Design in the United States, and the Metropolitan Museum of Design Detroit (MM-O-DD) is the city's only design museum. This month it is showing *SCORE: Sports by Design*, and the chapter is organizing an Engineering Expedition to see it.

The exhibition's subtitle is Play. Passion. Profession. — a deliberate arc from the games people love to the careers that produce them. What it actually surveys is the engineering and design work hidden inside sport:

- Sneakers and performance footwear
- Product and equipment design
- Team uniforms and apparel
- Arena and stadium architecture
- Motorsports and race car design
- Boxing and combat sports
- Sports branding and identity
- Fan experience and technology

Several of those are systems problems wearing a consumer face. Performance footwear is a materials and biomechanics optimization under a weight budget. Stadium architecture is crowd flow, structural load and broadcast infrastructure resolved in one envelope. Race car design needs no introduction to this membership. The exhibition is built to show the next generation how a love of sport becomes a career in design — which makes it a strong venue for members bringing students or family.

We will meet at Mudgie's Deli and Wine Shop for lunch and networking. It is a Corktown institution and one of the best sandwich counters in the city. The menu runs to generously built deli sandwiches — corned beef, pastrami, brisket, and the multi-meat house signatures — with housemade chips and pickles, plus salads for anyone wanting something lighter. There is a wine shop attached and a solid list of beer and cider by the glass.

RSVP: E-mail michael.vinarcik@incose.net by Friday, September 11 (so we can confirm headcount).

INCOSE Certification Information Session

Date: Tuesday, September 15, 2026, 11:00 AM - 12:00 PM EDT

Location: Virtual

Cost: Free

Join us and learn how INCOSE's Systems Engineering Professional (SEP) certification program works. This one-hour session covers the ASEP, CSEP, and ESEP credential requirements, the application and exam process, how experience and education are evaluated, and what it takes to maintain certification through professional development units. Whether you are weighing your first certification or preparing to advance to the next level, you will leave with a clear picture of the path and the resources available to you — including chapter and INCOSE study support.

We will also cover the SysML v2 Model User certification and the $75 discount OMG is offering through December 31, 2026 (code 1NC05EM3M75). If you have an OCSMP certification, use OMGSMUUP31026 to save $100. With the chapter's heavy SysML v2 programming this year — the April bootcamp, the June Vendor Showcase, and the August AI-assisted modeling session — this is an opportune moment to convert that experience into a credential while the discount is in effect.

Register at: https://lp.constantcontactpages.com/ev/reg/2k456bn/lp/b11b5b95-ca07-4e53-95b9-d0c52412c849

Celebrating Systems Engineering Excellence with the University of Michigan MRover Team and Systems Soirée at Relish

Date: Tuesday, September 15, 2026, 6:00 - 8:00 PM

Location: University of Michigan Ford Robotics Building (2505 Hayward St, Ann Arbor, MI 48109) / Relish Restaurant (610 Hilton Blvd, Ann Arbor, MI 48108)

Cost: $25 ($10 student) (Dinner included)

Join INCOSE Michigan for a special September dinner meeting as we visit the Michigan Mars Rover Team (MRover) on the University of Michigan's campus and present the INCOSE Foundation's Systems Engineering Excellence Award trophy.

MRover is a student-run, multidisciplinary team that designs, builds, and tests a complete Mars rover each year to compete in the University Rover Challenge (URC). At the 2026 URC finals—concluding May 30, 2026 at the Mars Desert Research Station in Utah, where the top 38 finalists from a field of 116 teams across 11 countries competed—MRover placed fifth overall, earned the highest score in the Autonomous Navigation mission, and won the first-ever INCOSE Foundation Systems Engineering Excellence Award, taking first place in the competition's Systems Engineering category with their rover, Phil.

The award is a fitting recognition of real systems engineering in action. Fielding a rover that navigates rough terrain, manipulates objects with a five-degree-of-freedom robotic arm, performs on-board science and sampling, and executes autonomous missions demands exactly the disciplines our members practice daily—requirements management, interface control, subsystem integration, verification, and risk management across mechanical, electrical, software, and science teams. This is systems engineering made tangible, by students.

We will tour the team's workspace and see the competition rover up close, present the INCOSE Foundation trophy, and then continue the conversation over dinner at nearby Relish Restaurant. It is a great opportunity to celebrate the next generation of systems engineers, talk shop with the team, and connect with fellow members.

Register at: https://lp.constantcontactpages.com/ev/reg/m6qvdnj

Sidequest Social: An Idiot's Guide to Wine

Date: Saturday, October 3, 2026, 6:00 PM

Location: Epiphany 313, 10103 Kercheval Avenue, Detroit, MI 48214

Cost: Varies (General Admission and Front Row tickets available)

Join your fellow chapter members for an evening that pairs hilarious stand-up comedy with a curated tasting of six wine varietals from around the world. The Australian smash-hit *An Idiot's Guide to Wine* has arrived in Detroit, delivering a rare blend of laughter and learning—whether you're a seasoned connoisseur or a complete beginner.

Why This Event?

The show was written by Merrick Watts, the only comedian in the world to hold a WSET (Wine & Spirit Education Trust) Level 3 qualification—a reminder that domain expertise and audience engagement aren't mutually exclusive. Systems engineers will appreciate the underlying challenge: distilling a complex, technical subject (wine) into an accessible, repeatable experience that lands consistently for a diverse audience. It's requirements decomposition and stakeholder communication, served by the glass.

This is a relaxed, social evening at the same Kercheval Avenue venue that hosted our Dungeon Cocktail Experience earlier this year—an ideal setting for members and guests to mingle.

Details:

- Age: 21+ with valid ID
- Language: English, performed by a local comedian
- Accessibility: Venue is ADA accessible
- Note: Alcohol consumption is voluntary; non-alcoholic options available for an additional fee
- Tickets: Reserve your own at https://feverup.com/m/667936

RSVP: Contact michael.vinarcik@incose.net if you plan to attend (we may coordinate dinner reservations if there is sufficient interest).

Save the Date: SysML v2.0 Requirements (Lockheed Martin)

Date: Tuesday, October 6, 2026, 6:00–8:00 PM

Location: Virtual

Partner Organization Events

SAE Detroit Section

AVL Tour and Open House

Date: September 16, 2026, 4:30 PM - 7:30 PM

Location: AVL Ann Arbor Technical Center, 1801 E. Ellsworth Rd, Ann Arbor, MI 48108

Cost: Free

AVL is a powertrain development, simulation and test engineering house, and a working test facility is about as close to a live verification-and-validation environment as most of us will stand in this year. Where a museum tour shows you the finished artifact, this shows you the instrumented middle of the lifecycle — how requirements become measurable acceptance criteria, and what it actually takes to prove a propulsion system does what the spec claimed. Members working in automotive, defense or any regulated domain will recognize their own V&V problems in someone else's building. Facility tours cap on headcount and fill quickly, so register early rather than deciding late.

Register at: https://www.sae-detroit.org/event-details/?id=499

PMI Great Lakes Chapter

PMI Great Lakes 2026 Professional Development Day — “Transforming Project Management in an AI World”

Date: Friday, September 18, 2026, 8:00 AM – 4:00 PM

Location: MSU Management Education Center, 811 W. Square Lake Rd, Troy, MI 48098

Cost: $220 members / $260 non-members

A full day of speakers, sponsor exhibits and structured networking built around a question our members face from the other side of the same program: what does AI actually change about delivery work, as opposed to what it is marketed as changing. The value for systems engineers is in seeing where program management is absorbing AI-assisted planning and estimation, because those are the interfaces our own processes have to meet. The INCOSE–PMI Memorandum of Understanding makes PMI Great Lakes programming a natural fit for members building cross-discipline depth, and at a single day in Troy this is the most accessible way to do it this fall. Early-bird pricing has closed and the cancellation window shuts at noon on September 9, so register before then if you intend to go.

Register at: https://pmiglc.org/professional-development-day

PMI Global Summit 2026 Comes to Detroit — "Built to Move"

Date: October 21-24, 2026

Location: Huntington Place Convention Center, Detroit

PMI's flagship annual conference, the Global Summit, lands in Detroit this October, putting a premier project-management event right in our members' backyard. This year's theme, "Built to Move," centers on navigating accelerating change—choosing agility over rigidity, shaping what comes next, and equipping professionals to stay relevant as the pace of work increases. For INCOSE Michigan members, it's a strong cross-discipline development opportunity under the INCOSE–PMI MOU, and a rare chance to attend a global-scale program without travel. The Summit also runs alongside PMI's Leadership Institute Meeting (LIM), which focuses on leadership training, PMI strategy, and collaborative breakout sessions for chapter leaders.

Register at: https://events.pmi.org/flow/pmi/gsdetroit26/landing/page/home

Engineering Society of Detroit

Engineers Get Hired Job Fair

Date: October 29, 2026, 2:00 PM – 7:00 PM

Location: Vibe Credit Union Showplace, 46100 Grand River Avenue, Novi, MI 48374

Cost: Non-members $20 through October 15, $25 after

ESD’s fall job fair regularly draws hundreds of engineers and technology professionals, with past employers including Ford, General Dynamics Land Systems, Dürr Systems, Ghafari, LG Energy Solution and MDOT. It is worth attending as a hiring manager as much as a candidate, and non-member registration includes a one-year ESD membership for first-time members. Job seekers can also post a resume to the ESD Job Bank at no charge.

Register at: https://www.esd.org/gethired/

Other INCOSE Chapter Events

Webinar 204: Agility as Resilient Emergent Behavior

Date: September 2, 2026, 11:00 AM – 12:00 PM EDT

Location: Virtual

Cost: Free

A framework for building agility into how systems and teams operate. The talk presents eight strategies as fundamental to SE agility—attentive situational awareness, common-mission teaming, shared-knowledge management, iterative incremental development, adaptable modular architectures, attentive decision making, continual integration and test, and being agile. Useful for practitioners and leaders applying agile principles within an SE lifecycle.

Register at: https://www.incose.org/event/webinar-204-agility-as-resilient-emergent-behavior/

AISE Café: MBSE Around the World — What Works, What Fails, and Why

Date: September 10, 2026, 11:00 AM – 12:00 PM EDT

Location: Virtual

Cost: Free

Model-Based Systems Engineering is widely accepted as the answer to managing complexity, so it is worth asking why the same methods produce very different outcomes in different organizations. Tim Weilkiens takes that question head-on in this AISE Café interview, arguing that MBSE success depends as much on organizational culture and process as it does on method and tooling. For members who are midway through a digital engineering transformation — or watching one stall — this is a candid look at the failure modes that rarely make it into vendor case studies. AISE is the Italian Chapter of INCOSE, and the Café series is open to members across chapters.

Register at: https://www.tickettailor.com/events/aise/2326027

Webinar 205: Product Line Engineering in Aerospace & Defense

Date: September 16, 2026, 11:00 AM EDT

Location: Virtual

Cost: Free

A practitioner-focused session with a notable industry panel. As Aerospace & Defense faces pressure to deliver increasingly complex, configurable products while accelerating innovation and maintaining compliance, this session draws product line engineering lessons from Lockheed Martin, Safran Seats, and PTC. Directly relevant to reuse, configurability, and engineering-process transformation in SE.

Register at: https://www.incose.org/event/webinar-205-accelerating-aerospace-defense-transformation-with-product-line-engineering-lessons-from-lockheed-martin-safran-seats-and-ptc/

INCOSE Enchantment Chapter: Systems Engineering of the James Webb Space Telescope

Date: September 16, 2026, 4:45-6:00 PM MDT

Location: Virtual

Cost: Free

A compelling applied-SE case study on one of the most complex systems ever fielded. The JWST—launched December 25, 2021, as NASA's successor to Hubble—was designed to observe “first light” objects in the nascent universe and the evolution of galaxies. High-interest for members who enjoy large-scale integration and lifecycle SE stories. Registration is by request; contact the chapter via the event page for the meeting invitation.

Register at: https://enchantment.incose.org/event/enchantment-chapter-systems-engineering-of-the-james-webb-space-telescope/

Other Events

Dossin Great Lakes Museum:
Dossin After Dark

Date: Friday, September 25, 2026, 6:45 – 11:00 PM

Location: Dossin Great Lakes Museum, 100 Strand Drive, Belle Isle, Detroit, MI 48207

Cost: Various

The Dossin sits on Belle Isle looking out at the shipping channel, which makes it an unusual place to spend an evening: the freighters passing the windows are the working continuation of the maritime system the museum documents. This year's fundraiser pairs that view with live jazz, a strolling dinner, a cigar-rolling demonstration, and a live auction, then moves out to the riverfront patio for late-night bites and dancing. Doors open at 6:45 PM for Supporter-level guests, with dinner at 7:30; Patron and Honorary Host Committee tickets add a 6:00 PM Captain's Tent reception and early access to the silent auction. Proceeds support the museum's work connecting Detroit's history to the river that shaped it. The event is 21-and-over, cocktail attire, with complimentary valet parking.

Register at: https://1066.blackbaudhosting.com/1066/Dossin-After-Dark

Detroit Month of Design

Detroit is the only UNESCO City of Design in the United States, and every September Design Core Detroit marks it with Detroit Month of Design — this year the 16th edition, running September 1–30 with more than 100 events across the city. Most are free. The 2026 theme is "Design Moves the Future," and the organizers have been explicit that the program shifts from theory to practice: less about what design might accomplish, more about what Detroit designers are actually building.

That framing is closer to our work than it may sound. Detroit's UNESCO designation rests on the city having invented industrial design — the discipline that emerged when mass production forced a separation between how a thing works and how it is made, sold and used. Several events this month sit directly on systems engineering territory: mobility, urban systems, requirements discovery from end users, and materials selection.

Our Engineering Expedition to SCORE: Sports by Design on September 12 is part of this festival — see Upcoming Chapter Events above.

Finding Your Way Around 100+ Events

The festival organizes programming under three solution tracks: Mobility, Transportation & Access; Climate Resilience & Sustainability; and Civic & Community-led Design. The event calendar itself filters three other ways, which is the practical route to a short list:

- **By event type** — Exhibitions, Installations, Talks, Open Studio, Experiences, Mobility, Workshops
- **By design discipline** — Architecture, Industrial/Product Design, Fashion Design, Graphic Design, Technology, Mobility, Sustainability & Climate Action
- **By neighborhood** — 18 of them, useful for planning a single day rather than crossing the city

For our members, the Technology, Mobility, and Sustainability & Climate Action filters do most of the work.

Full calendar: detroitmonthofdesign.org/events

Three Worth Your Time:

Cars at The Station

Date: Friday, September 11, 2026, from 4:00 PM (multiple dates)

Location: Michigan Central, Detroit

Cost: See event listing

A future-forward look at the tech, mobility, and culture of the Motor City, held on the Michigan Central campus. This is the festival's most direct engagement with the industry most of us work in, inside a working mobility innovation district. Two other festival events run at the station the same evening — Fridays at the Station and City of Design Talk: At the Station — so one trip covers three.

Details: Cars at The Station

Reimagining Detroit: From Legacy Assets to Future City

Date: Tuesday, September 15, 2026

Location: Fox Theater, Detroit

Cost: See event listing

A panel exploring how adaptive reuse, strategic reinvestment, and thoughtful urban planning can unlock Detroit's future. Legacy assets are, in systems terms, a large installed base with long service life, deferred sustainment and constrained modification options — a problem shape our members will recognize from platforms rather than buildings. Note that this shares a date with our Certification Information Session and the MRover dinner meeting; check the event listing for times before committing.

Details: Reimagining Detroit

Design Jam: Inclusive Product Design Workshop

Date: Friday, September 11, 2026, from 4:00 PM (multiple dates)

Location: Shared with registrants

Cost: See event listing

Interdisciplinary teams prototype new adaptive outdoor recreation product ideas with and for people with disabilities — requirements elicitation straight from end users, with prototyping and feedback in the room. A compressed demonstration of an argument most of us make in principle and rarely get to practice.

Details: Design Jam

Also Worth a Look

- Anyspace? Whatever. — multiple dates through September, 11:00 AM–5:00 PM, Museum of Contemporary Art Detroit. rootoftwo's installation imagines an equitable "smart city," putting surveillance networks, algorithmic decision-making and civic data infrastructure up for scrutiny. Smart cities are a recognized INCOSE application domain.
- DVN Interior Detroit — Tuesday, September 22 (two-day), CCS Taubman Center. A panel on the future of automotive interiors, presented by Driving Vision News.
- Understand the Present, Design the Future — Tuesday, September 22, Civilla. A journey mapping workshop: human-centered design to uncover barriers and drive change. Stakeholder analysis by another name.
- Making Better Things with Daniel Liden: Toyota Lecture Series — Friday, September 18, College for Creative Studies. Exhibition and reception for the Sustainable Material Showcase.
- Donut Shop Open Studio: Parts of the Process — Monday, September 14. A behind-the-scenes tour of a furniture manufacturer's process.
- Detroit's Evolving Neighborhoods — Wednesday, September 16, Three Squared, Inc. How Cochrane Commons is leveraging mass timber and innovative design to shape Detroit's housing future.
- From Waste to WANTED — Thursday, September 24. A panel on Lawrence Tech University product design students' award-winning furniture project.
- 3D Printing Workshop — Saturday, September 19, ISAIC. Research ideas, design shapes, and prep files for making your own 3D-printed item.
- Eastern Market After Dark — Thursday, September 17, Eastern Market Shed 2. Billed as Detroit's biggest creative night out, and the best option for members bringing family.
- Industrial Heritage to Industrial Design — Sunday, September 6, SpaceLab Detroit. The second City of Design Conversation, on what design practice inherits from Detroit's manufacturing base.
- Shinola Presents: Designing for the Future — a three-part conversation series with Periodicals on time: how we measure it, use it, and carry it forward. Conversation #2 is titled "Time & Systems." Conversation #1, Time & Craft, is Wednesday, September 9.

Design Core also recruits festival volunteers throughout September, and runs the Street Design Challenge, a 48-hour UNESCO Cities of Design competition for university students.

Historical Corner

Three September anniversaries, and one question underneath all of them: how do you know a system is good enough before you commit to it? On September 9, 1966, President Johnson signed a law that answered by insisting requirements be written so that compliance could be measured, then making the builder prove it. Three days later, Gemini XI launched on a mission whose purpose was to rehearse — to retire risk incrementally, with a crew aboard and an abort still available. Ten years after that, on September 3, 1976, Viking 2 landed on Mars, where the integrated system could never be rehearsed in its operating environment, nothing could be aborted, and no one was flying. Objective requirements, incremental rehearsal, and design under irreducible uncertainty are three answers to the same problem, and each has a cost the others do not.

This Month in SE History: "Stated in Objective Terms"

September 9, 1966 — Sixty Years

On the morning of September 9, 1966, roughly two hundred people gathered in the White House Rose Garden to watch President Lyndon Johnson sign two bills: the National Traffic and Motor Vehicle Safety Act and the Highway Safety Act. Johnson told them that nearly three times as many Americans had died in traffic crashes during the twentieth century as had died in all the nation's wars. Annual highway fatalities were then running close to fifty thousand a year.

For an audience in Michigan the political history is familiar ground — the Ribicoff hearings, Nader's book, an industry that had spent decades arguing that safety belonged to the road and the driver rather than to the vehicle. What is less familiar is that Public Law 89-563 contains a sentence that any systems engineer would recognize immediately, and that this sentence, not the politics, is why the law still governs the work Michigan engineers do every day.

A Statute That Reads Like a Requirements Standard

The Act directs that each motor vehicle safety standard "shall be practicable, shall meet the need for motor vehicle safety, and shall be stated in objective terms." Those three clauses are, respectively, a feasibility criterion, a traceability criterion, and a verifiability criterion. They are the same attributes any requirements quality checklist applies today, written into federal law in 1966 and still in force, essentially unchanged, at 49 U.S.C. § 30111.

The third clause carries the most engineering weight. A standard stated in objective terms is one whose satisfaction can be determined by measurement rather than by opinion. In practice this means each Federal Motor Vehicle Safety Standard pairs a minimum performance threshold with the test conditions and procedures under which that threshold is demonstrated. The requirement and its verification method are issued together, as one artifact.

Performance, Not Design

The standards specify what a vehicle must achieve, not how to build it. A thirty-mile-per-hour barrier impact with instrumented dummies is a performance requirement; it does not tell an engineer where to put structure, how to tune a restraint, or what material to use. The design space stays with the manufacturer.

This was a deliberate choice, and it is the reason the regime absorbed six decades of technical change without being rewritten. Energy-absorbing steering columns, dual braking circuits, laminated windshields, and side marker lights were among the early results, but the standards that produced them were written as outcomes to be met rather than parts to be fitted.

Outcome-based requirements have a characteristic failure mode, and Standard 208 supplied the textbook case. The passive restraint rule let a manufacturer meet one occupant-protection outcome by either of two means: airbags or automatic seat belts. By 1981 it was clear that roughly ninety-nine percent of new cars would get automatic belts, and that most of those could be detached and left detached — satisfying the standard as written while defeating the protection it existed to provide. NHTSA rescinded the requirement. In Motor Vehicle Manufacturers Association v. State Farm, decided in 1983, the Supreme Court held the rescission arbitrary and capricious, faulting the agency above all for never considering the obvious alternative of requiring airbags alone. The engineering reading is independent of the administrative law: when a requirement admits several compliance paths, suppliers converge on the cheapest one, and if any admissible path fails to deliver the outcome, the defect is in the requirement rather than in the supplier.

The Schedule Was the Hard Part

Congress gave the new agency until January 31, 1967 to issue the initial standards — under five months from signing. At the single industry meeting granted before the deadline, on January 25, 1967, Dr. William J. Haddon Jr., director of the National Traffic Safety Agency, told manufacturers that the standards were too unfinished to discuss in specifics, and that his agency's own staffing shortfall was what precluded the fuller dialogue everyone in the room wanted.

Congress had, however, done one sensible thing: it required that the initial standards be based on existing safety standards, including those already developed by the Society of Automotive Engineers and others. Twenty-three were proposed; twenty were issued for passenger cars on January 31, 1967, effective for vehicles manufactured on or after January 1, 1968. Reusing already-validated content is what made an otherwise impossible schedule survivable. Standards written from scratch were not required until a year later.

That reuse had a second effect worth naming. The material Congress directed the agency to draw on was largely industry-authored — Society of Automotive Engineers practice and existing federal procurement standards — and several of the twenty-three proposed standards were modified in response to manufacturer comment before issue, which drew public criticism at the time. The criticism was fair as far as it went. But the condition underneath it is permanent and is not a scandal: the regulated party almost always knows more about the technology than the regulator does. It has the test fleets, the failure data, the tooling, the manufacturing experience, and most of the engineers. A five-month-old agency that by its own director's account lacked the staff for detailed technical dialogue was never going to out-specify Detroit on how to build a steering column. What makes the regime work anyway is the level at which it writes. Because the standards state outcomes rather than designs, the agency never needed to match the industry's design knowledge — it needed to know what the vehicle must achieve and how that would be measured, which is a far smaller body of expertise to hold, and then to test independently against it.

Self-Certification: Where the Burden of Proof Sits

The Act established what remains one of the most consequential verification decisions in the regime, and one that still surprises engineers who move between markets. The United States does not use type approval. NHTSA does not approve, certify, or endorse any vehicle. Instead, each manufacturer certifies that its own products comply with every applicable standard, exercising "reasonable care" in doing so, and affixes the certification label itself.

The agency then tests independently to audit that claim, and enforces against manufacturers whose certifications prove unfounded. Verification cost, verification evidence, and the associated liability all sit with the builder. The regulator holds the sampling authority and the penalty. Neither this nor the type-approval model is inherently correct; what matters is that the choice was made explicitly and the enforcement mechanism was designed to match it.

Closing the Loop from the Field

The Act's second major provision is the one every practicing engineer eventually meets. A manufacturer that determines a safety-related defect exists must notify purchasers and remedy the defect without charge. The legislative history is blunt about why: deficiencies in past industry practice regarding notification and correction of defects made mandatory procedures necessary.

This is the origin of the modern recall. Structurally, it is a field feedback path made compulsory, and it exists because compliance at the moment of manufacture proves conformance to a standard — not the absence of hazard. Verification against a finite set of requirements will always leave residual risk, and the notification-and-remedy obligation is the mechanism that catches what the standards did not anticipate. NHTSA's own defect screening now draws on owner questionnaires, field reports, and referrals to decide where to investigate.

Detroit's Response, and What Followed

The industry did not welcome the bill. Four days before the signing, with the conference report already through both chambers, Automotive News led its September 5, 1966 edition with a headline announcing that a tough safety law had stripped the auto industry of its freedom. Yet John Bugas, the Ford vice president who had represented the Automobile Manufacturers Association at the hearings, called the bill constructive legislation — and one practical reason is worth noting: the Act substituted a single national requirements baseline for the prospect of divergent standards emerging state by state. Manufacturers lost the argument over who would set the requirements. They gained one requirements set instead of fifty.

More than sixty FMVSS are now in force, codified at 49 CFR Part 571 and grouped by function: the 100-series for crash avoidance, the 200-series for crashworthiness, the 300-series for post-crash integrity. Assessments of the Act's effect vary, and honest ones acknowledge that vehicle standards, road design, and driver behavior all moved over the same decades. Total annual fatalities in fact kept climbing after 1966, to an all-time peak of 54,589 in 1972, before beginning a long decline; the fatality rate per vehicle mile traveled fell dramatically after 1967, though analysts disagree on how much of that decline to assign to federal vehicle standards specifically.

SE Lessons for Practitioners

- **"Stated in objective terms" is a requirement about requirements.** Congress did not merely demand safe cars; it demanded that the criteria for safe cars be written so that satisfaction could be measured. That is a quality gate applied to the requirement itself, upstream of any product. The working test is simple and unforgiving: if you cannot describe the measurement that would settle whether the requirement is met, you have written an aspiration, not a requirement.

- **Issue the requirement and its verification method as one artifact.** Each FMVSS pairs a performance threshold with the conditions and procedures under which it is demonstrated. Separating the two — requirements in one document, test plans written later by someone else — is how organizations discover at verification time that a requirement was never testable as written. Bind them at issue.

- **Performance requirements preserve the design space; design requirements consume it.** A thirty-mile-per-hour barrier test says nothing about structure, materials, or restraint tuning. Every requirement expressed as a solution rather than an outcome is design authority quietly transferred away from the people best positioned to exercise it — and a constraint that will still be there when the technology has moved on.

- **Check every compliance path against the outcome, not just against the wording.** A performance requirement satisfied by any of several means will be satisfied by the cheapest of them. Standard 208 permitted airbags or automatic belts; the industry converged almost entirely on detachable belts, which met the standard and defeated its purpose, and the rescission that followed was struck down in State Farm. Before issuing a requirement with alternatives, walk each alternative through to the outcome and ask whether the worst admissible implementation still delivers it. If it does not, the requirement is the defect — and discovering that in the field is far more expensive than discovering it at review.

- **Place the burden of proof deliberately, then build the audit to match.** Self-certification puts verification evidence and liability on the manufacturer and gives the regulator sampling and enforcement authority. Type approval inverts it. The failure mode is not choosing one over the other; it is leaving the choice implicit, so that everyone assumes someone else holds the evidence. Name the party who must prove conformance, and size the independent check accordingly.

- **When the schedule is immovable, constrain the solution space rather than the quality bar.** Facing a five-month statutory deadline, Congress required the first standards to be drawn from existing, already-validated industry standards. That is reuse mandated as a schedule strategy, and it is a better answer than the more common one of keeping the scope and quietly lowering the evidence threshold. The friction was real even so — compressed schedules extract payment somewhere.

- **Where the supplier knows more than you do, specify outcomes and own the measurement.** The asymmetry is structural. The organization that builds a thing accumulates more knowledge of it than the organization overseeing it, and no realistic amount of staffing closes that gap. An oversight body that tries to compete on design detail will lose, and will produce requirements that are simultaneously weaker and more constraining than it intended. The durable position is the one the Act took: define the outcome, define the test that settles it, and keep independent authority to run that test. Expertise you cannot match is not a reason to specify less rigorously. It is a reason to specify at a different level.

- **A requirements regime without a field feedback path is incomplete.** Certified compliance demonstrates conformance to the standards that existed when the vehicle was built. It does not demonstrate the absence of hazard, because the standard set is finite and the world is not. The mandatory notification-and-remedy obligation exists precisely to catch what verification could not anticipate. Any program that treats passing verification as the end of the safety argument has no mechanism for the hazards it failed to imagine.

- **The property that makes a requirement durable can become the binding constraint.** Objective, performance-based phrasing is why 1966 language still governs vehicles its drafters could not have pictured. It is also why driving automation is genuinely hard to regulate under it: writing an objective, measurable pass/fail criterion for a system whose competence is statistical and context-dependent is a different problem from specifying a barrier impact. This is live work in Michigan right now, and it is a requirements-engineering problem before it is a policy one.

This Month in SE History: Gemini XI — What a Rehearsal Is For

September 12, 1966 — Sixty Years

Three days after Johnson signed the Safety Act, and ten years before Viking 2 reached Mars, Charles "Pete" Conrad Jr. and Richard F. Gordon Jr. lifted off from Launch Complex 19 aboard a Titan II GLV at 14:42 UT. Their launch window was two seconds wide.

That number is the whole architecture in miniature. Gemini XI was to attempt a direct-ascent rendezvous — catching the Agena Target Vehicle on the first orbit rather than over several — and a first-orbit rendezvous only closes if launch occurs at a precise instant relative to the target's ground track. A two-second window was not a display of nerve; it was a derived requirement, the unavoidable price of the rendezvous profile chosen. Five maneuvers brought the crew to rendezvous at 1 hour 25 minutes ground elapsed time, and the two vehicles docked nine minutes later, using less propellant than expected.

Getting there had already cost two launch attempts. Gemini XI was counting down on September 9 when the launch crew, checking the vehicle after propellant loading, found a pinhole leak on a weld seam of the Titan's first-stage oxidizer tank. The scrub was announced at three that morning, some ten hours before the president reached the Rose Garden. The propellants were unloaded, the leak plugged with sodium silicate and covered with an aluminum patch, and the attempt reset for the 10th — which was scrubbed in turn when the Agena's autopilot behaved oddly during checkout. The unit was later found to be working correctly, but the anomaly could not be cleared in time. With a two-second window, a hold is a scrub: there is no room to work a problem and still go. The program paid that price twice before the vehicle ever left the ground.

Three Objectives, Three Different Kinds of Result

The mission fired the Agena's primary propulsion system to raise apogee to about 1,374 kilometers, which remains the altitude record for crewed Earth orbit. It concluded with the first fully automatic, computer-controlled reentry flown by the United States, splashing down on September 15 about a mile and a half from the planned point and within three miles of the prime recovery ship USS Guam, after a mission of 2 days, 23 hours, 17 minutes.

The tether experiment fared less cleanly. Gordon's task on his first extravehicular activity was to take the free end of a 30-meter tether stowed on the Agena and secure it to the Gemini's docking bar, so the two could be set into slow rotation. He completed it, but the work proved far harder than ground rehearsal had suggested. Fighting the suit's pressure without adequate restraints, he overheated, his visor fogged, and the EVA was terminated after roughly half an hour against a plan of nearly two. The tethered configuration then proved awkward to stabilize.

Nothing broke. The hardware performed. What failed was the prediction of human workload in the environment — a verification failure located in the ground simulation rather than in the flight system. Gemini's EVA difficulties across several missions are what drove NASA toward neutral buoyancy training and toward treating restraints and handholds as first-class interfaces rather than afterthoughts.

SE Lessons for Practitioners

- **Derived requirements inherit the architecture's cost.** A two-second launch window was not chosen; it fell out of selecting direct-ascent rendezvous. When you pick an architecture you have implicitly accepted every constraint it derives, including the ones nobody surfaces until the operations team reads the mission rules. Part of the bill came due before launch: two scrubs in three days, because a window that narrow converts any unresolved anomaly into a twenty-four-hour slip. Trace those constraints early and price the architecture accordingly.

- **Verification environments need validating too.** The tether task was verified on the ground and still surprised the crew. The defect lay in the simulation's fidelity — gravity, suit pressure, restraint, and thermal load were not represented well enough for the result to transfer. Before trusting a test result, ask which environmental factors the rig does not reproduce, and whether the quantity being measured depends on them.

- **Retire autonomy risk where a human can still take over.** The first fully automatic reentry was flown with two experienced pilots aboard, on a short mission, in Earth orbit, with manual mode available. That is the correct place to demonstrate a capability you intend to depend on later. Viking had no such option — which is precisely why Gemini's incremental demonstrations mattered.

- **Emergent behavior appears at the system boundary you did not draw.** Two vehicles joined by a flexible tether behave as neither vehicle's control system was designed to handle. Whenever an architecture creates a temporary composite system — mated configurations, towed loads, coupled plants — the dynamics of the composite need their own analysis and their own tests.

This Month in SE History: Viking 2 — Verification Without a Rehearsal

September 3, 1976 — Fifty Years

At 22:37:50 UT on September 3, 1976, the Viking 2 lander settled onto Utopia Planitia at 47.97 degrees north, 134.29 degrees east, some 6,500 kilometers from where its twin had landed six weeks earlier. Nobody on Earth watched it happen. At Mars distance, one-way signal time ran to nearly twenty minutes, so by the time the first telemetry from atmospheric entry reached the Deep Space Network, the vehicle had already been on the surface, or had failed somewhere on the way to it, for some time. Every decision in the descent had been made by the spacecraft, executing a sequence loaded before separation.

This is the condition that defines Viking as a systems engineering problem. The landing was a single-shot, no-abort, no-operator event on a surface no vehicle had ever successfully characterized, and there was no way to test the integrated system in its operating environment before flying it.

There was prior art, and it was not encouraging. The Soviet Union had delivered two landers to Mars in 1971. Mars 2's descent module entered too steeply after an onboard course correction overshot and struck the surface on November 27, becoming the first human-made object to reach Mars, though not intact. Mars 3 soft-landed successfully on December 2 — the first controlled landing on another planet — opened its petals, began transmitting, and fell silent after about fourteen and a half seconds, having returned a partial image of seventy lines. The cause has never been established, and it is not even certain whether the fault lay in the lander or in the orbiter relaying it. Both vehicles had arrived during a planet-wide dust storm. So the sample available to Viking's designers was two attempts by a capable program, yielding one crash and one unexplained loss inside a quarter of a minute. That is the evidence base against which a single-shot, no-abort architecture had to be justified.

A Requirement That Propagated Everywhere

Viking carried three biology experiments intended to detect microbial metabolism in Martian soil. That single mission objective generated a constraint that touched nearly every subsystem: the lander could not carry terrestrial organisms, both to satisfy COSPAR planetary quarantine obligations and to prevent the project from contaminating its own experiment.

The solution was terminal dry-heat sterilization. The assembled lander was sealed inside a two-piece bioshield — a pressurized fiberglass cocoon roughly 3.7 meters in diameter that isolated the vehicle from biological contamination until Viking had left Earth's atmosphere — and the whole assembly was baked. Every part inside had to survive the cycle.

The consequences were not incidental. Part selection narrowed. Gyroscopes, tape recorders, batteries, and adhesives all needed rework or requalification. Fastener preloads and solder joints had to be analyzed for the thermal exposure. Non-metallic materials were tested for outgassing behavior. Organic components across the lander were catalogued and analyzed, and an aniline-free hydrazine was developed specifically so the descent propellant would not compromise the science. Sterilization was not a process step bolted onto the end of assembly. It was a top-level requirement that reached three levels below the system boundary into component engineering.

How Mass Became the Thing That Ended the Mission

The clearest requirements cascade in the program starts with a number nobody would call a requirement. Each orbiter had a launch mass of about 2,328 kilograms, of which roughly 1,445 kilograms — some 62 percent — was propellant and attitude control gas, and it carried an encapsulated lander capsule of roughly 1,200 kilograms, of which about 600 kilograms would reach the surface. That combined mass drove an eleven-month transit to Mars rather than the roughly five months typical of the Mariner missions. The longer flight time then dictated an increased spacecraft design life, larger solar panels to absorb the additional degradation from solar radiation, and additional attitude control gas.

That last item is where the chain closes. The orbiters used nitrogen jets at the solar panel tips to hold a Sun-and-Canopus reference; without that reference, the panels drift off the Sun line and the spacecraft loses power. Viking Orbiter 2 lost its attitude control gas to a leak in its propulsion system and was commanded off on July 25, 1978, after 706 orbits. Orbiter 1 began running short the same year, but careful conservation planning stretched reduced-rate science operations another two years until the supply was finally spent and power was commanded off on August 7, 1980, after 1,489 orbits by JPL's count, or 1,485 by the NSSDCA archives.

A mass decision propagated through trajectory design to mission duration to consumable sizing, and the consumable so sized is what determined end of life for both orbiters — by depletion on one, by a single leak on the other. Attitude control gas had no redundancy and no resupply, so any path that emptied the tank ended the mission.

Autonomy as a Consequence of Physics

The guidance, control and sequencing computer was not an efficiency measure. Light-time made real-time control impossible, so autonomy was a derived requirement of the mission's geometry — and JPL described the computer as one of the greatest technical challenges of the program.

It consisted of two general-purpose computer channels with plated-wire memories, each with an 18,000-word storage capacity; one channel operated while the other stood in reserve. Among the programs it held were instructions capable of running the lander's first 22 days on Mars with no contact from Earth, to be updated by command once communications were established. Entry, descent, and landing ran entirely from stored sequence: aeroshell deceleration behind a cork-like ablative heat shield, mortar-ejected parachute, heat shield separation, then three hydrazine engines spaced 120 degrees apart on the lander sidebeams, each throttleable across roughly a ten-to-one range from about 276 to 2,667 newtons.

Each of those engines carried an unusual cluster of eighteen small nozzles, adopted specifically to fan the exhaust over a wide angle so the descent would not alter the surface or disturb the chemical and biological experiments the lander was about to perform. A propulsion design choice existed to protect a science requirement. The engine and the experiment were not independent.

Three Critical Functions, Three Redundancy Strategies

The lander carried a radar altimeter providing altitude data from 1,370 kilometers down to about 30 meters, and a separate terminal descent landing radar using four continuous-wave Doppler beams to measure horizontal velocity to within roughly one meter per second during the final phase. Both were classified as essential to mission success, and both were made redundant — but not in the same way. The terminal descent landing radar was designed to function on any three of its four beams, degrading gracefully within a single unit. The radar altimeter instead carried identical sets of electronics that could be switched to either of two antennas, one mounted through the aeroshell and one beneath the lander.

A third pattern appears on the orbiter. The visual imaging subsystem used twin slow-scan television framing cameras with optical axes offset by 1.38 degrees, and the two cameras were completely redundant — each with its own control, electronics, and power. Not degraded modes, not shared switchable elements, but full functional duplication down to the power supply.

Three functions on the critical path, three different redundancy architectures, each fitted to the failure modes and packaging of the function in question. No single policy generated all three.

The Sites That Could Not Be Certified

The most instructive episode in the program is that the site certification team rejected both prime landing sites — and that the architecture had been built to let them.

The orbiters carried four allocated primary functions: transport the landers to Mars, perform reconnaissance to locate and certify landing sites, act as communications relays, and conduct their own science. Site certification was not a contingency bolted on when trouble appeared. It was a mission function assigned to a specific element, and the imaging subsystem’s stated purposes began with aiding selection of landing sites that were both safe and scientifically interesting. The sequence — arrive, image, certify, only then separate — was architected years in advance.

Sites had been selected using Mariner 9 data. Viking 1’s touchdown was planned for July 4, 1976, the United States Bicentennial. When the orbiter arrived and began imaging, and Earth-based radar observations were folded in, the team concluded that the Chryse prime site was geologically more varied and possibly more hazardous than expected. In the language of Masursky and Crabill’s Science paper, it “was not certifiable.” The project did not land. The certification effort was extended and substantially redesigned, a compromise site roughly 900 kilometers to the northwest was identified, and Viking 1 landed on July 20.

The same thing then happened again. After examining high-resolution photographs, the team judged the planned Viking 2 site unsafe as well, and a replacement at Utopia Planitia had to be certified in time to support the September 3 landing. Two prime sites, selected with the best data available at the time, were both overturned by the team the architecture had empowered to withhold certification.

The team also wrote down what it had lacked. Masursky and Crabill close their paper by listing the instruments and observations that would have made certification tractable: higher-resolution cameras, radar altimeters, and terrain hazard avoidance capability in the landing system. That is a program stating, in the open literature, a requirement it could not satisfy itself. All three were eventually built. Mars Global Surveyor's laser altimeter produced the global topography every later site selection has rested on; the Mars Reconnaissance Orbiter's HiRISE camera resolves surface features at tens of centimeters and supplied the stereo hazard maps used to certify sites for Phoenix, Curiosity, InSight, and Perseverance; and Terrain-Relative Navigation finally moved hazard avoidance onto the vehicle itself in 2021. The gap Viking identified in 1976 took forty-five years to close, and it closed because someone specified it precisely enough to be built against.

The Bicentennial date was not a technical requirement, and the project treated it accordingly. That distinction — between a schedule commitment and a mission commitment — is the whole lesson.

Structure, Accountability, and What the Landers Did

Responsibility was explicitly assigned and explicitly transferred. NASA Langley Research Center held project management from the program's inception in 1968 until April 1, 1978, when the Jet Propulsion Laboratory assumed it mid-mission. JPL designed and built the orbiters and ran mission control and the Deep Space Network interface; Martin Marietta Aerospace in Denver designed and built the landers; Lewis Research Center in Cleveland owned the Titan-Centaur launch vehicles. James S. Martin Jr. was project manager and Dr. Gerald A. Soffen project scientist.

The stated operational lifetime requirements were 120 days in orbit for the orbiters and 90 days of surface operation after landing. Against a lander science payload of roughly 91 kilograms, the return was substantial: the orbiters mapped essentially the entire planet at 150 to 300 meters resolution and selected areas at about 8 meters, with the two orbiters returning some 52,000 images between them and the landers more than 4,500 from the two surface sites.

Viking Lander 2 returned its final data to Earth on April 11, 1980, having operated 1,281 sols — about 1,316 days. Lander 1 made its last transmission in November 1982, and the overall mission was declared at an end on May 21, 1983. Not everything worked: the seismometer on Lander 1 never functioned after landing, and Lander 2's recorded only one possible seismic event, though it did usefully supplement the meteorology data. The biology instruments found unexpected chemical activity in the soil but no clear evidence of living organisms, and the gas chromatograph/mass spectrometer found no organics at the parts-per-billion level. One experiment — Labeled Release — returned a positive response that its principal investigator argued for decades was biological; the mainstream reading, strengthened after Phoenix detected perchlorates in 2008, attributes it to soil oxidant chemistry. Viking reported the result as unresolved. It still is.

Sidebar: Fifty Years Later — Viking and the Rovers

The contrast with current Mars entry, descent, and landing practice is sharper than the family resemblance suggests.

- **Where you can land.** Viking's landing ellipse was large — roughly an order of magnitude greater in area than the 150-by-20-kilometer ellipse the Mars Exploration Rovers achieved in 2004. Curiosity's guided entry brought it to about 20 by 7 kilometers in 2012. Perseverance landed in 2021 inside an ellipse of about 7.7 by 6.6 kilometers, about a third the area of Curiosity's. Viking's site selection problem was to find a large region that was safe everywhere. Perseverance's was to find a small region that was safe enough, and then hit it.

- **How it is achieved.** Perseverance added two capabilities Curiosity lacked. Range Trigger deploys the parachute based on computed distance to target rather than a fixed velocity, cutting dispersion by more than half. Terrain-Relative Navigation, implemented in the Lander Vision System, images the surface between roughly 4.2 and 2.2 kilometers altitude, matches it against onboard maps, and diverts the sky crane toward a safe touchdown point. Viking had radar altimetry and a landing radar; it knew how high it was and how fast it was descending, but not where it was in any map sense, and it had no ability to reject a hazard it happened to be descending onto.

- **Compute.** Perseverance carries redundant RAD750 processors with 256 MB of DRAM and 2 GB of flash, each capable of at least 400 million instructions per second — on the order of 1,700 times Viking's throughput and thousands of times its memory, plus field-programmable gate arrays dedicated to vision processing across 23 cameras.

- **What did not change.** Redundancy, radioisotope power, the aeroshell-parachute-powered-descent architecture, full autonomy through EDL, and the impossibility of a full-system rehearsal. Fifty years of capability growth moved the boundary of what can be verified in flight software and simulation; it did not move the fundamental constraint. Nobody has yet landed on Mars twice with the same vehicle.

The honest summary is that modern EDL did not eliminate Viking's risk. It converted a large amount of positional uncertainty into a much smaller amount, and spent the recovered margin on reaching scientifically valuable terrain that Viking's designers would have ruled uncertifiable. Both postures are defensible. What matters is that each was matched to the quality of environmental knowledge actually available at the time.

SE Lessons for Practitioners

- **A cross-cutting constraint is a system requirement, not a process step.** Sterilization was allocated from a mission objective down to part selection, materials, fastener preload, and propellant chemistry. Constraints of this shape — contamination control, EMC, cybersecurity, functional safety — do not decompose neatly into one subsystem's scope. If your architecture cannot show where such a constraint lands at every level, it has not actually been allocated.

- **Trace the cascade all the way to the consumable that ends the mission.** Combined mass drove transit time, which drove design life, which drove solar array sizing and attitude control gas quantity — and attitude control gas is what ended both orbiters, years later: one by depletion, one by a leak that emptied a tank nothing could refill. Early architectural decisions set consumable budgets long before anyone writes a consumables requirement. Follow the chain to the end and ask which resource your design has quietly committed you to running out of first — and whether a single failure can empty it early.

- **Allocate environment certification as a function, not as a review.** Viking did not merely staff a team to bless the landing sites. It assigned site reconnaissance and certification to the orbiter as one of four primary functions, designed the imaging subsystem with that purpose stated first, and sequenced the mission so certification necessarily preceded lander separation. The team could reject both prime sites because the architecture had given it the instrument, the schedule position, and the authority to do so. Where success depends on assumptions about the operating environment, ask which element owns the job of testing them and whether the plan lets that element's answer actually stop the program.

- **Record the requirement you could not meet.** Viking's certification team could not close its own instrument gap, so it published the gap: higher-resolution imaging, radar altimetry, and onboard hazard avoidance. Successor programs built all three. A lessons-learned artifact functions as a feedback path only when it names a capability specifically enough that someone else can fund and design against it — "site data was insufficient" would have funded nothing. When your program hits a limit it cannot afford to solve, write that limit down as a requirement for whoever comes next, in the terms they will need to procure it.

- **Distinguish a schedule commitment from a mission commitment before the pressure arrives.** July 4, 1976 was attractive, publicly known, and entirely arbitrary. It was surrendered because the project had never carried it as a requirement, so when the data went against it there was nothing to trade. The time to establish which dates are negotiable is well before anyone asks you to accept a marginal result to hold one.

- **Allocate redundancy per function, not per policy.** Three functions the project could not afford to lose received three different redundancy architectures: graceful degradation across four Doppler beams, switchable duplicate electronics across two antennas, and fully independent twin cameras with separate power. A blanket rule such as "all critical items shall be dual redundant" would have produced a worse design for at least two of them. Criticality sets the requirement; the failure modes, duty cycle, and packaging should set the architecture.

- **Bound the autonomy problem rather than maximizing autonomy.** Viking did not attempt general onboard intelligence in 18,000 words of plated wire. It executed a pre-validated sequence inside an envelope its designers had characterized, with enough stored capability to survive 22 days of silence. The engineering question was never "how autonomous can we make it" but "what is the smallest set of decisions this vehicle must make without us, and can we verify all of them on the ground?"

- **Coupled requirements produce coupled designs, whether you model them or not.** Eighteen nozzles per descent engine existed because a propulsion subsystem could otherwise invalidate a science instrument two subsystems away. Interfaces of this kind — where one element's entirely nominal operation degrades another element's function — are the ones that escape interface control documents and surface during integration.

Viking at 50

NASA has released a commemorative "Viking: 50 Years on Mars" poster, along with wallpapers and phone screens, as part of its fiftieth anniversary materials. The poster places the Viking lander alongside the missions that followed it — Spirit and Opportunity, InSight, Perseverance, and the proposed SkyFall helicopters — which makes it a reasonable visual for the compare-and-contrast above. Print and digital files are free to download at science.nasa.gov/resource/viking-50-years-on-mars-poster/, and the broader anniversary collection of stories, images, and 3D models is at https://science.nasa.gov/mission/viking/viking-50-years-on-mars/.

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This article was drafted with assistance from Claude.ai by Anthropic.

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Portions of this newsletter were researched and drafted with assistance from Claude.ai (Anthropic, 2026).