The Chief Engineer's Role in Creating High Performance Teams and Successful Products; Learning from History

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Chief Engineer Case Studies

- History gives us examples of how to design aircraft as well as how not to.
- Consider 4 World War II and later cases, chronologically:
  - North American Aviation P-51 Mustang — *Designer*: Edgar Schmued
  - Bell Model 30 — *Designer*: Arthur Young
  - Heinkel He-162 — *Designer*: Siegfried Günter
  - AIM-9 Sidewinder missile — *Designer*: William McLean
- Each was designed and built extremely quickly by a small team led by a remarkably similar Chief Engineer.
- Goal of this presentation:
  - Describe what they did,
  - Describe how they did it
  - Recommend what we can apply from their experiences

Edgar Schmued and the P-51

Ed Schmued was born in Austria, raised in Germany. Saw a Wright Flyer when he was 8 and decided to work on airplanes. His family was too poor to send him to college. Instead, he apprenticed at an engine manufacturer and taught himself engineering by self study.

Emigrated to Brazil to work for GM and then to the US to work for Fokker. Eventually this became North American Aviation.

Birth of the P-51 Mustang

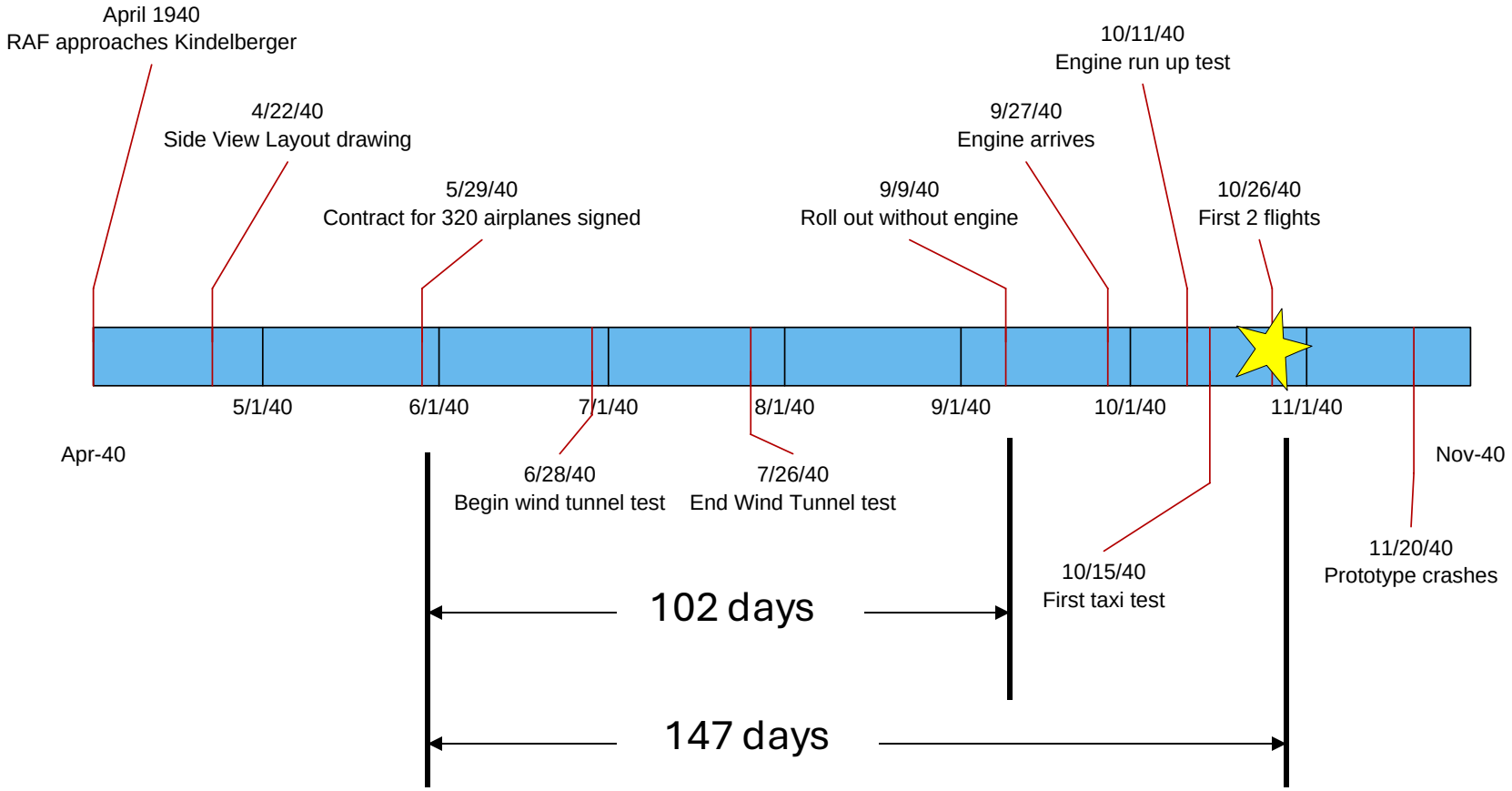
- At the beginning of World War II the British Royal Air Force was in desperate need of fighters. In early 1940 they approached “Dutch” Kindelberger of North American Aviation to license build Curtis P-40s.
- Kindelberger counter proposed making an all-new fighter (which hadn’t been designed yet).
- The RAF agreed – if the plane was ready in 120 days, the time it would take to retool to make P-40s.
- North American had minimal previous fighter design experience and the contract was not in line with the wishes of the US Government. It was a purely private venture.
- Kindelberger chose Edgar Schmued as Chief Designer.

The Prototype NA-73X

Kindelberger's instructions were to make it fit a 63kg, 1.8m pilot, arm it with four 20mm cannons, and go as fast as possible using an Allison engine.

It also had to be taken apart, shipped to England, and reassembled. (DFMA)

Timeline of the NA-73X



The 2nd prototype was the first production airplane, the 3rd the first to go to England. The Mustang was one of the most successful fighters of the period. Approximately 16,000 were produced.

Arthur Young and the Bell Model 30

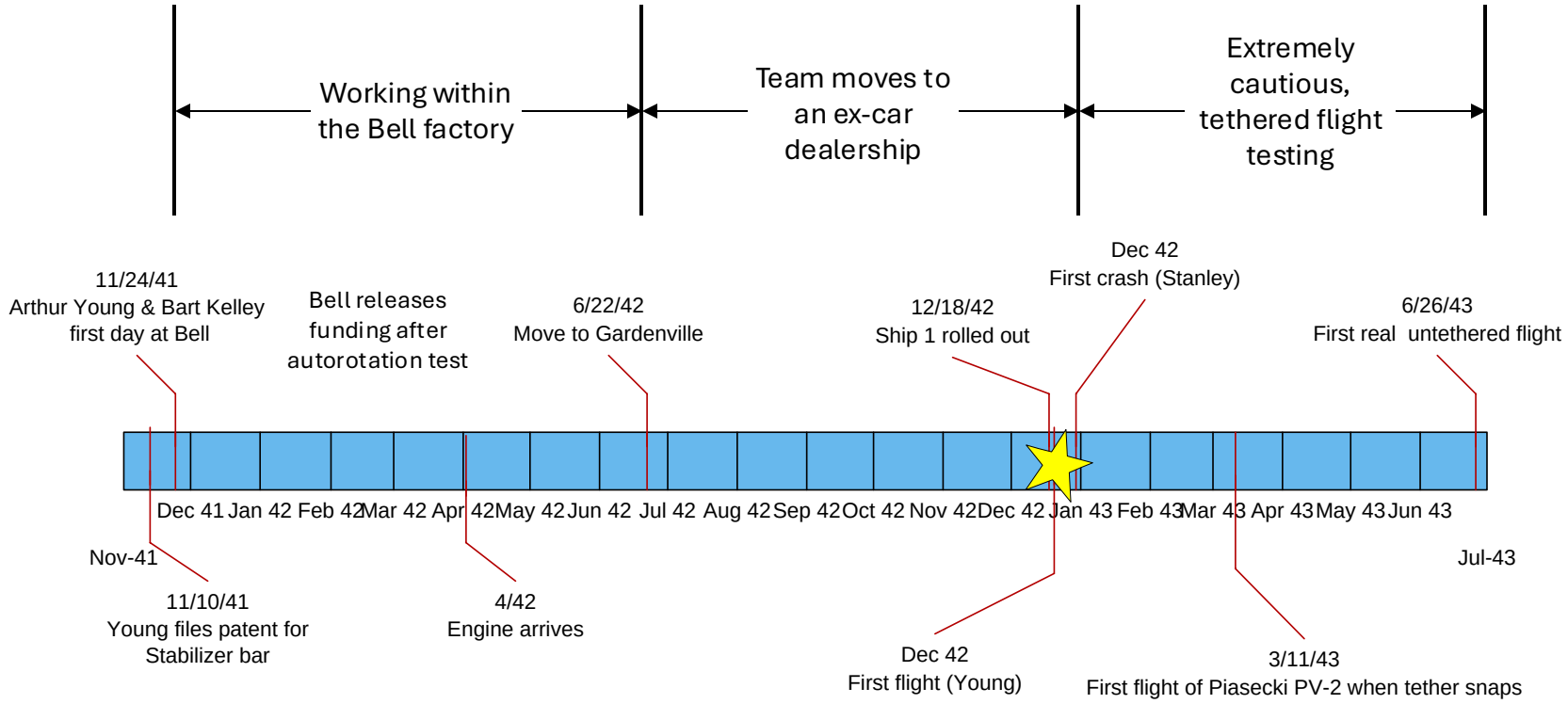
Arthur Young was a natural tinkerer as a child. He wanted to be a philosopher but graduated with a Math degree from Princeton.

In 1927 he decided he had to solve a challenging technical issue in order to become a philosopher. He thought making a helicopter would be enough of a challenge.

Birth of the Bell Model 30

- As early as 1941 Larry Bell was dreaming of a Post-War period of prosperity in which private aircraft, especially helicopters, were as common as cars.
- Bell hired Arthur Young in September, 1941 to design and build *commercial* helicopters for private individuals despite there being few successful designs.
  - Despite the rapid build up of government aviation contracts at the time, Bell saw this as an exclusively commercial product, not military.
- Initial budget was $250,000 to *design* 2 prototypes. Young designed and *built* 4, often by going outside and around the Bell bureaucracy.

Timeline Bell Model 30, Ship 1



Bell Model 30, Ships 1, 2, and 3 were research prototypes only and not intended for production. They led to the highly successful Model 47, the first commercially certified helicopter, which was in production from 1946 to 1974. Total production was >5000. Ship 1 is on display in the Smithsonian NASM and a Model 47 at the Museum of Modern Art in New York.

Arthur Young on YouTube including video of first flight and crash

https://www.youtube.com/playlist?list=PL63C95D4821B4CFCE

Siegfried Günter and the Heinkel He-162

Siegfried and Walter Günter were identical twins. They were fascinated by airplanes from an early age. Designed their first award winning airplane in their 20's.

Ernst Heinkel hired them because they had "that certain something" as designers and shared his passion for speed. They designed many of Heinkel's most successful airplanes.

Photo used with permission of David Myhra

Birth of the He-162

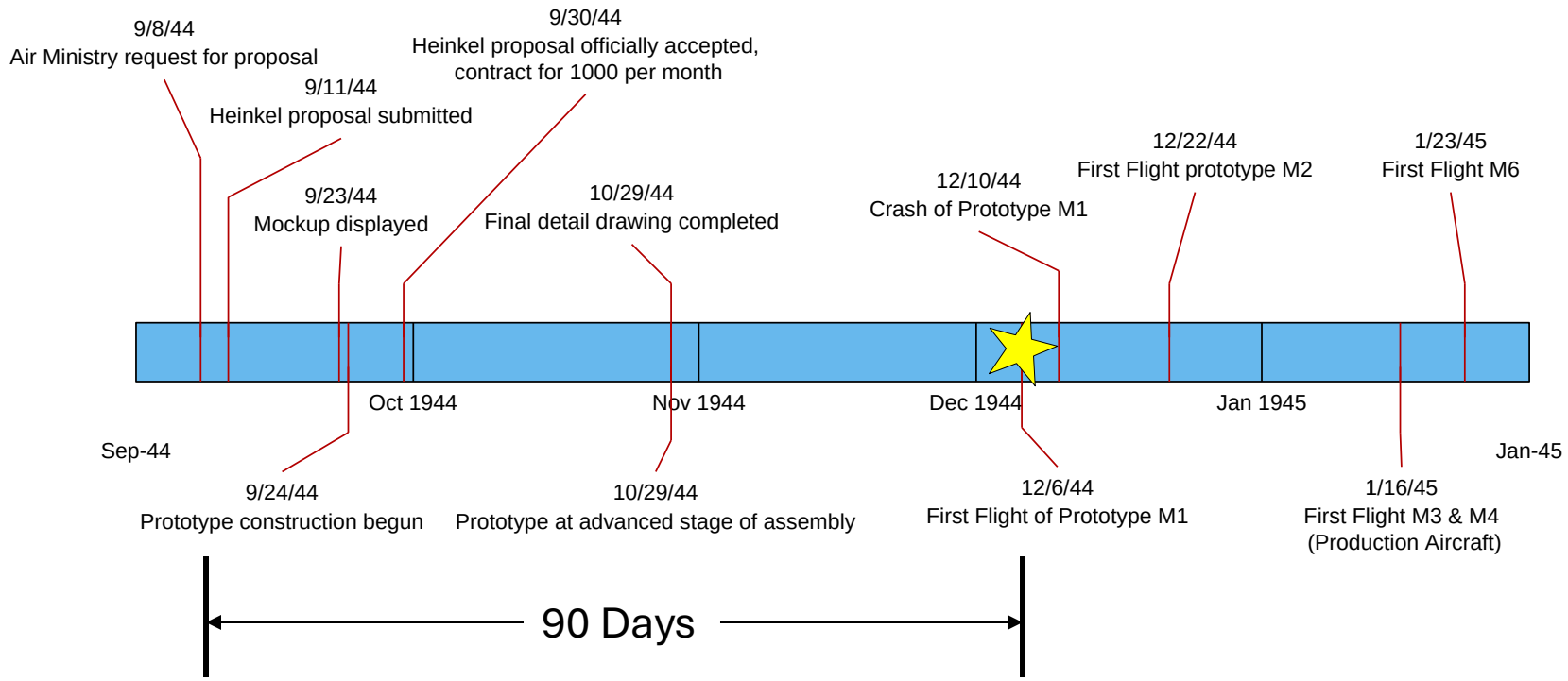
German Air Ministry released an urgent request for a jet fighter in 1944. The spec called for the plane to be in series production within 4 months and to be built at a rate of 1000 to 4000 per month out of non-strategic materials. Design life was 5-10 hours in combat.

Several firms considered the design goals to be impossible and refused to bid on it.

He-162 in testing by US Air Force in 1946, at what's now Edwards AFB.

US Government photo

He-162 Timeline



Production lines for prototype development, pre-production, and quantity production aircraft started essentially simultaneously. Full flight test program running in 1/45. Squadron evaluation in 2/45. Production: 80 in 3/45, 200 in 4/45, 500 ready to assemble 5/45, 1000 to be completed in 6/45.

Bill McLean and the Sidewinder

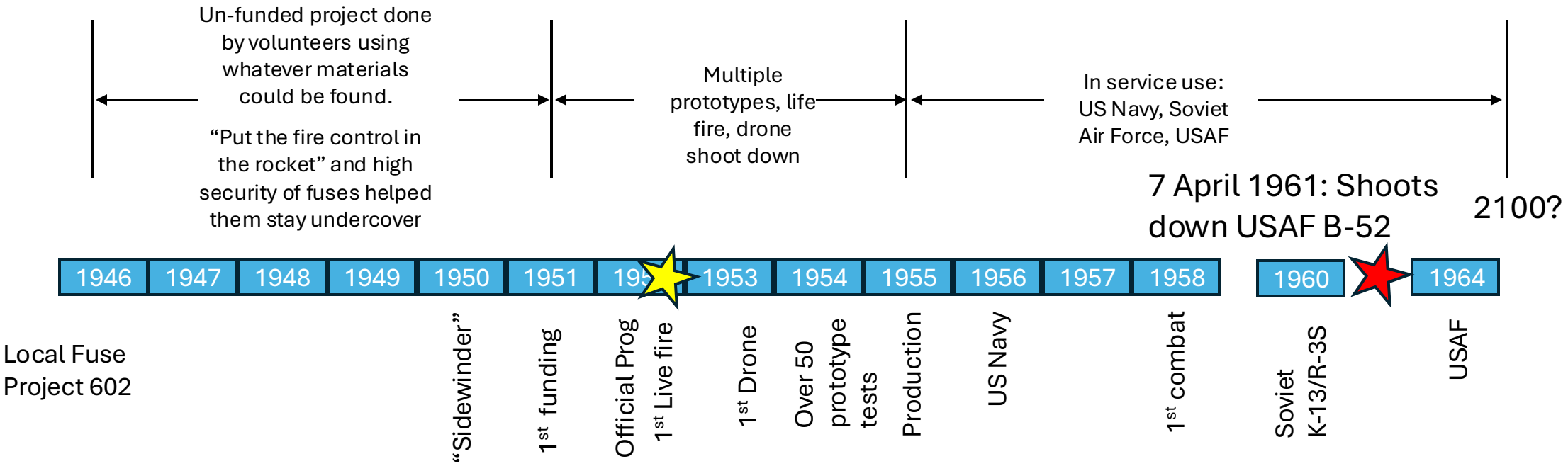
- Bill was taught at an early age to be frugal and how to fix things. His mother taught him to knit, crochet, and use a sewing machine before he was 6. His father taught him to repair cars, build houses, plumbing and wiring.
- Bill could build electronic circuits and complicated machines without drawings. He only made drawings for others.
- He was a PhD physicist.

Birth of the Sidewinder

- WW2 saw the first attempts at air-to-air infrared guided missiles. Bill McLean was Technical Director at the Naval Weapons Center, China Lake and decided that they should try to design one.
  - They had no mandate (and had been told not to)
  - No budget, no authorization
  - No requirements or even anyone asking for one.
- What he did have was a crew of talented, highly motivated people at an isolated base in the desert that could do the impossible
- The result was the AIM-9 Sidewinder. Over 110000 have been made and are expected to remain in service most of this century.

AIM-9 Sidewinder Timeline

Note long periods of slow effort and then breakneck speed



China Lake was a joint Navy and commercial operation based on finding good people and setting them on challenging problems. Bill McLean did was slow gathering of information until the real problems stood out. Then, the focus shifted to the most critically necessary components developed very quickly. Trying something out is better than figuring it out. Requirements would only be written after a system had been proven in the lab.

Active duty Navy pilots meant actual future users. They defined many of the "must haves"

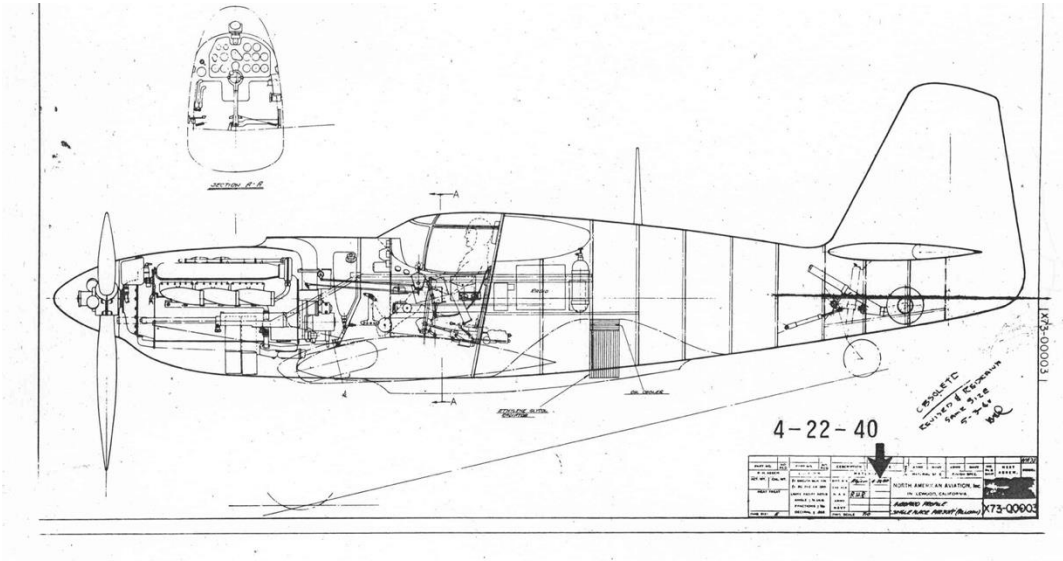
Common Themes

- Highly technically competent chief designer/engineer involved in many design issues.
- Small, dedicated, highly skilled team with entrepreneurial spirit. Mutually supportive and motivated, in part, by not wanting to let each other down. Everyone was expected to contribute.
- Clear focus on a common goal.
- Strong support from company chief executive

- Note also that all of these products required changes from their original, prototype form and each of them went through some redesign.

Chief Engineer/Designer Experience

- “Do ahead” approach (TRIZ inventive principle)
  - Schmued had notebooks of designs for “the ideal fighter,” as well as modular design elements he could adopt rapidly to fit new airframes.
  - Young spent 12 years building helicopter models studying first principles of helicopter flight.
  - Günter created a study for a jet fighter in July 1944 that he rapidly modified to create the design layout for the He-162.



Chief Engineer/Designer Inventiveness

- Ed Schmued and team:
  - P-51 designed from skin outer contour in
  - Chrome plating process to build up out of tolerance parts
  - Laminar flow wing
  - Thrust inducing radiator
- Arthur Young and team:
  - Teetering rotor
  - Rotor stabilizer bar
  - Bubble canopy (Model 47)
- Siegfried Günter and team:
  - Engine position on top of airplane
  - Tricycle landing gear (not completely new but very rare)
  - Ejection seat
  - Evidence of area rule design on preliminary concept
- Bill McLean and team:
  - Extensive reuse of common parts
  - Rapid test-redesign-test cycling
  - Used fighter pilot experience as part of design
  - Missile controlled by change in target location, the missile didn’t know where it was

Small, Entrepreneurial Teams

- **Each project team was quite small**
  - NA-73X: max 49, average 38; Model 30: max 32, average 15, Sidewinder: 25 engineers and techs
- **They were highly motivated and focused**
  - People chosen for skill and fit with rest of team
  - Enduring team chemistry: Günter twins and Karl Schwärzler, Arthur Young & Bartram Kelley, Ed Schmued, Ed Horkey & Julius Villepique
  - Evidence of flat org structure; all worked for the chief designer
  - Little to no silo mentality within Engineering or Manufacturing
  - NA-73X team worked 16 hour days, 6 days a week, took off at 6:00PM on Sunday. He-162 team worked similar hours during design, then two 12 hour shifts, 7 days a week during production.
- **Pattern of "moonshine" type actions**
  - Young brought in his own machine tools, often worked at night
  - Gardenville team isolated from Bell plant, allowed them to build 4 prototypes with the budget authorized for 2.
  - Long pattern of Heinkel hiding projects from official view
  - China Lake took full advantage of their desert location and track record to regularly bend the rules, volunteer projects are done on lunch break—which is 8 AM to 5 PM

Clear Focus on Common Goal

- **Projects had highly visible, extremely challenging technical and schedule goals.**
  - Small team & small shop meant clearly understood status.
  - Indications of strong internal motivation for performance; everyone worked hard to not let down their coworkers.
  - Schmued created a schedule wall. Each person estimated their task durations and put them on the wall. Strong sense of personal drive and accountability meant people tended to be overly optimistic with estimates. Visual control: Everyone could see the schedule and the status was updated daily.
  - Schmued checked with each person each day
  - Daily Bell team meetings at Schmaltz's roadhouse included Young's "problem of the day." Everyone was expected to offer opinions/solutions no matter what their role. At this time there were literally hundreds of helicopter projects in work, nearly all failed but Young's team knew the competition was out there.
  - Weekend working sessions at McLean's house.

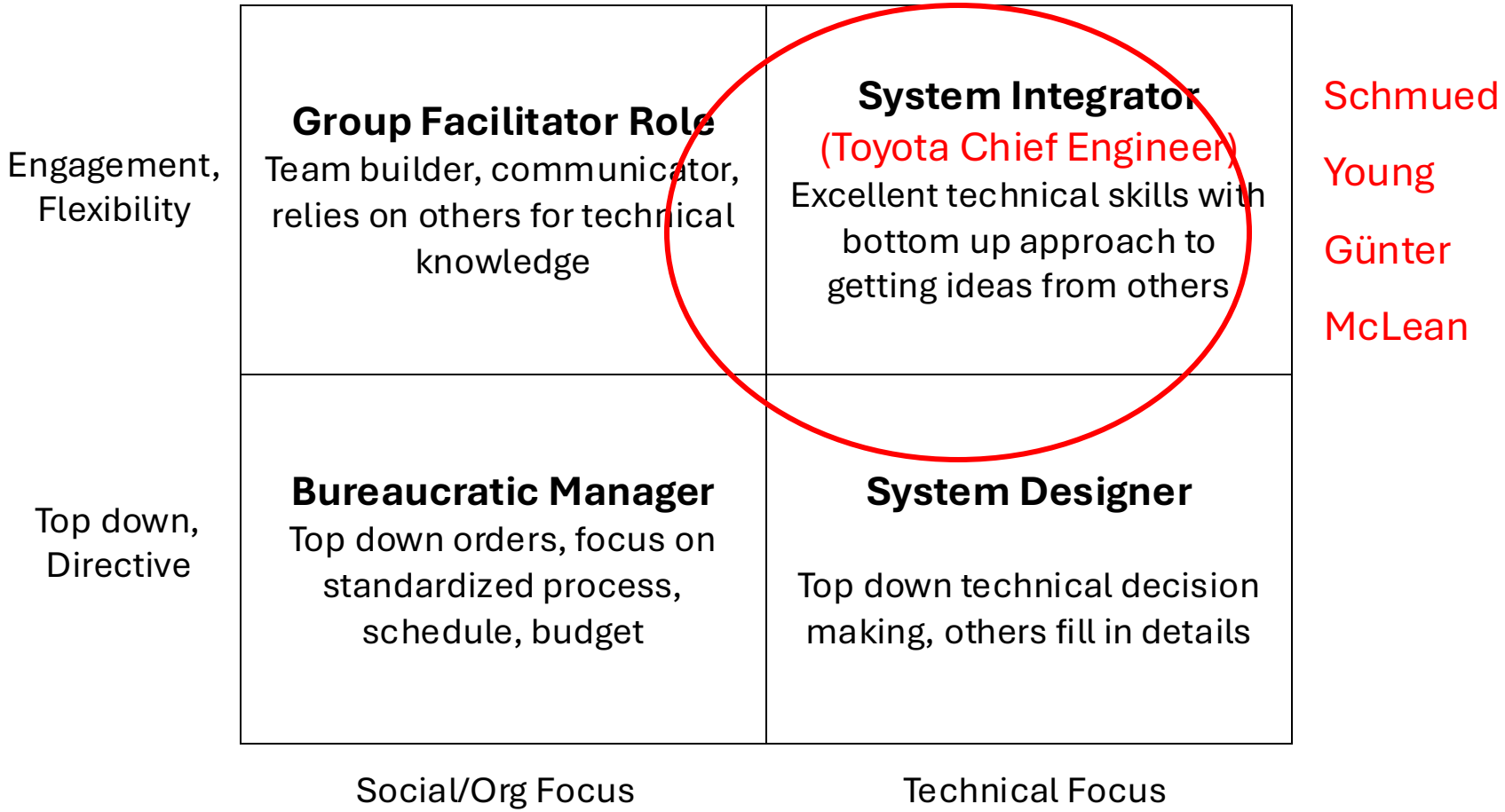
Impact of Company Chief Executive

- Dutch Kindelberger valued R&D funding in advance.
  - *“Nobody ever pulled a rabbit out of a hat without putting it there in the first place.”*
- Larry Bell believed strongly in preparing for the Post War economy by having products ready. He felt a personal responsibility for ensuring jobs for his employees after War production was halted.
- Ernst Heinkel regularly and routinely funded development projects he did not tell the government about.
  - Hired Werner von Braun to build rocket powered plane
  - Hired Hans Joachim Pabst von Ohain to build jet engines
  - He-178: world’s first jet powered aircraft, first flight 8/27/39
  - Obsessed with setting speed records
  - Boasted that his company *initiated* rather than *followed* trends.
- Each Chief Executive regularly and routinely met with their chief engineers as friends as well as coworkers.

Necessary Conditions for Organizational Success

- USAF Col. John Boyd's studies of organizational success across history showed four necessary conditions:
  - A common goal and focus of attention shared by all
  - Trust throughout all levels of the organization
  - Highly technically competent & skilled people
  - Delegated decision making based on clear understanding of the leader's intent.
- Each of these Chief Engineer/Designers created an organization that had these conditions.

History Through a Lean Lens



Model created by Jeff Liker and Jim Morgan to describe the role of the Toyota Chief Engineer.

Conclusions and Recommendations

- Keep product development teams as small as possible during initial phases of the development process.
- In early PD avoid having any organizational or functional boundaries. Each team member should contribute their skills to an integrated, whole product without regard to imposed limitations.
- Seek out and reward technical excellence and “working together” attitude in equal measure
- Chief Engineer/Integrators should be technically revered leaders capable of bringing out the best in their teams.

- **These are not compromises**; the goal should be challenging technical assignments accomplished under the guidance of a technically excellent leader and with peers we trust and respect.

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