The Science and Art of Educating Future Space Cost Engineers

Lessons Learned from the Space Station Design Workshop (SSDW) at the University of Stuttgart

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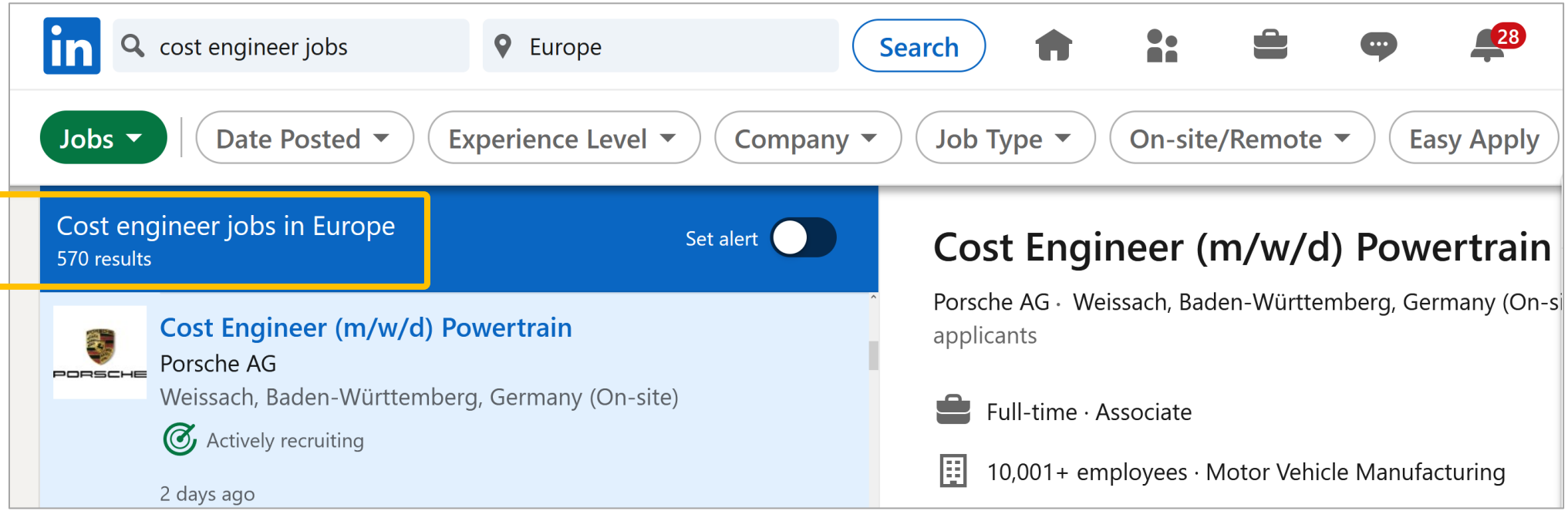
Space Cost Engineering Conference, ESA ESTEC, Noordwijk, Netherlands, 15–16 September 2022

Picture: Winning design for floating space station in Venus high atmosphere, SSDW 2019

Future (Space) Cost Engineers

This section provides some background on job market trends and demographics.

Cost Engineer seems to be a profession in high demand



- **A random LinkedIn search for “cost engineer jobs” in “Europe” delivered >500 hits**
- **Of course, there are many different job profiles for different domains, e.g., automotive vs. aerospace; industry vs. agency; early phase studies vs. production improvement**

Cost Engineer (ESA-ESTEC)

Noordwijk, The Netherlands, Sapienza Consulting [1369]

FIELD(S) OF EXPERTISE	JOB TYPE	EDUCATION	DEADLINE
Aerospace Engineering /Business Administration and Finance	Permanent	Master	CLOSED

About this job

We are recruiting a Cost Engineer for Sapienza to work on our Customers Site (ESA-ESTEC) who will be giving Costs Engineering Support to the Directorate of Technology, Engineering and Quality.

Responsibilities

- Bench-marking and calibrating internal and external cost models
- Accountability records consisting in comparing in a structured manner the external estimates and prices versus the internal estimates
- Provision of Cost Estimate reports according to the ESA standards
- Cost Estimates including schedule and cost risk estimates
- Cost models development. This includes cost, schedule, and risk aspects
- Projects data collection, analysis, normalization and entry into the existing Cost Engineering database
- Preparation of cost estimates in support of ESA projects, based on technical, programmatic and procurement information
- Analyses of industrial contractor estimates and prices
- Participation to Tender Evaluation Boards and associated cost related panels
- Participation in ESA project reviews
- Support to industrial contracts negotiations
- Cost engineering tasks in Concurrent Design Facility studies

Profile

- Master's Degree in Engineering or relevant
- At least 4 years of relevant work experience
- System engineering skills are a benefit
- Basic economics knowledge
- Knowledge of costs models
- Broad knowledge of current developments in the space industry
- Knowledge of ESA and its programmes and projects is an asset
- Good communication skills
- Reliability, objectivity, thoroughness, and initiative
- Ability to work independently and establish good working relations with relevant actors in ESA and industry
- Ability to readily assimilate input data and providing timely output
- Fluent in English; knowledge of another ESA member-state language is an asset

Contact:

Candidates must be eligible to work in the EU

Please send your CV (in English) as soon as possible, but no later than **14/07/2020** to **jobs@sapienzaconsulting.com**

Space Cost Engineers are a special subgroup

unison Cost Engineering

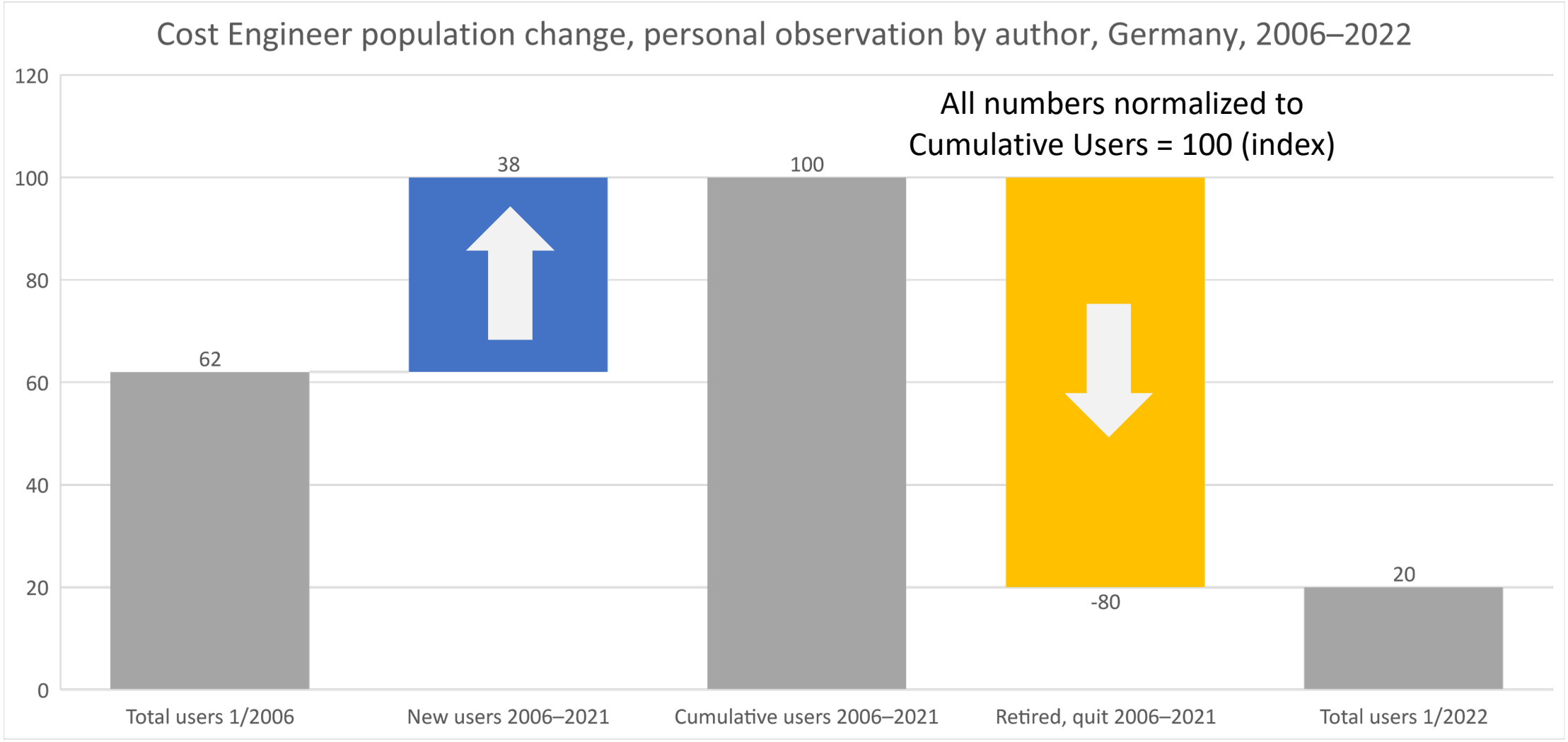
- At least 4 years of relevant work experience (1)
- System engineering skills are a benefit (2)
- Basic economics knowledge
- Knowledge of costs models (3)

- Ability to readily assimilate input data and providing timely output (4)

When you read this job advert, some questions come to mind:

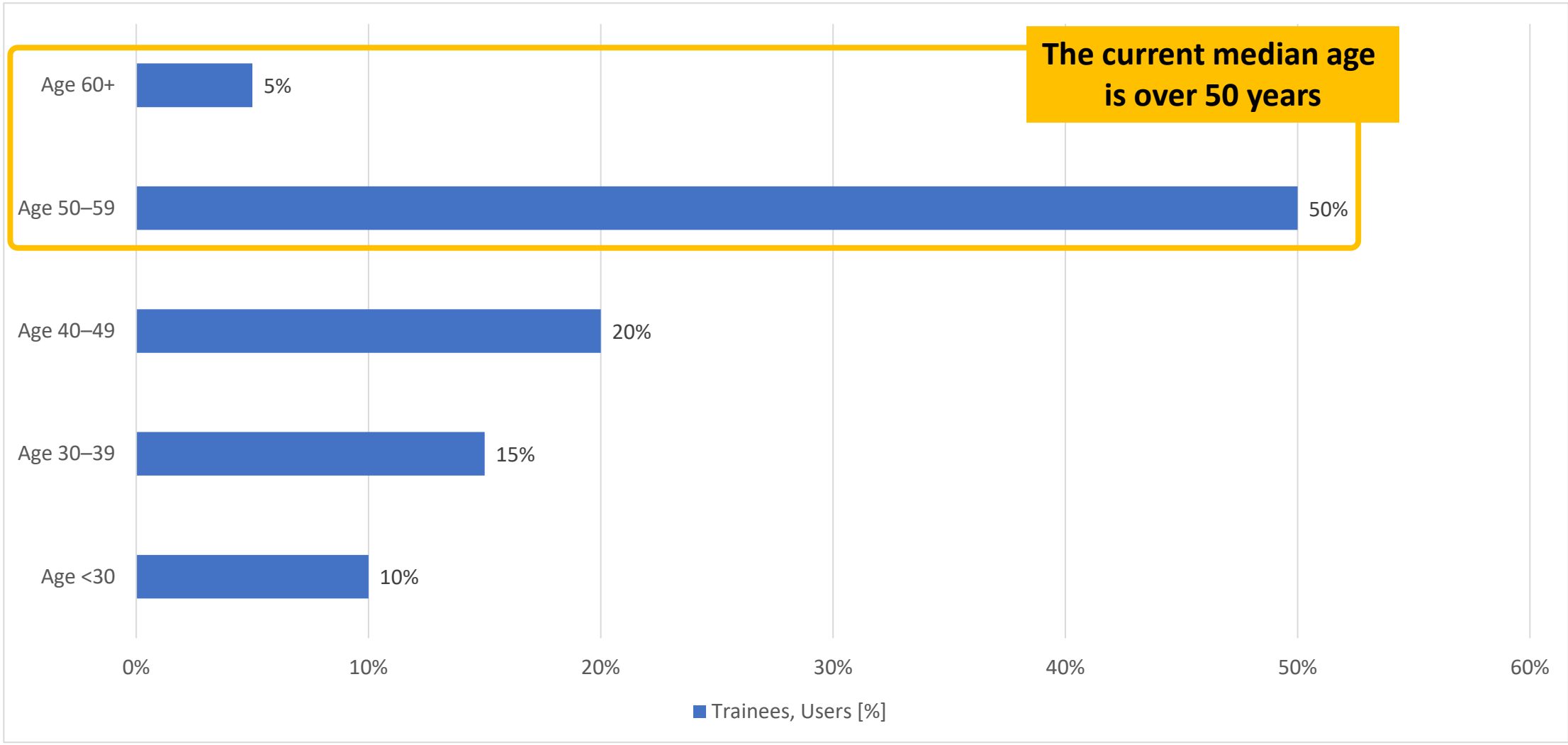
1. **Who shall provide you the first 4 years of work experience?**
2. **If you were a systems engineer, why would you pursue a cost engineering job instead?**
3. **Who shall train you in cost models?**
4. **Who shall teach you how to find and assimilate input data?**

A personal survey from 2022 shows: Attrition and loss of knowledge are real



Disclaimer: These are not product of a professional survey! Data shown are based on personal observations by the author. Errors excepted, use at your own risk.

Changing demographics need a strategy to retain cost engineering knowledge



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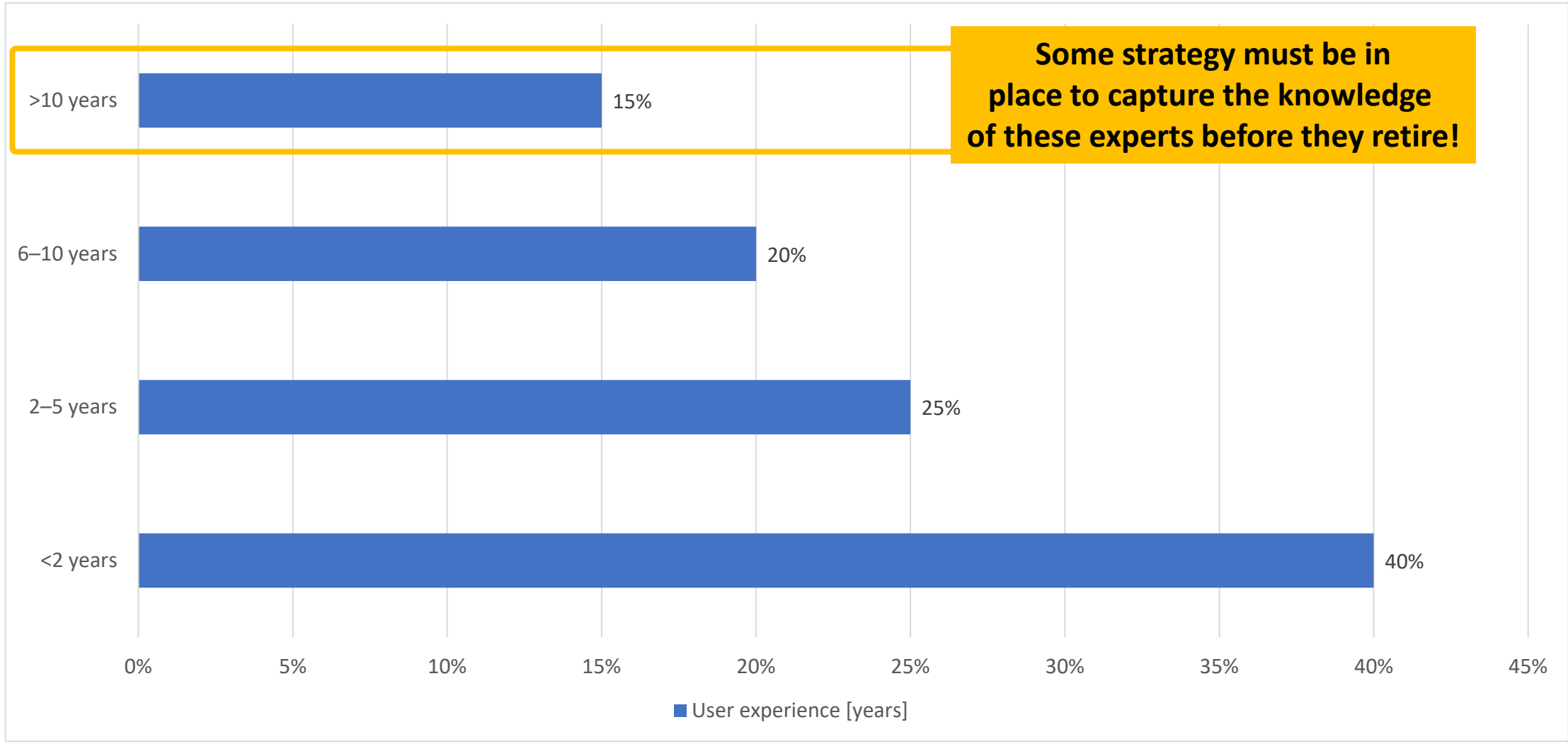
Experienced users have become fewer in recent years



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Users and trainees can be classified into three different categories

»The Naturals«

- Feel a calling to cost engineering, study out of own interest
- Actively seek training
- Help to advance the field of cost engineering

»The Pragmatists«

- Nominated by superior after a formal assess-ment of suitability
- Do a decent job, might advance from good to great

»The Slow Horses«*

- Condemned to administrative purgatory after failing previous assignment
- Want to leave as soon as a better option arises

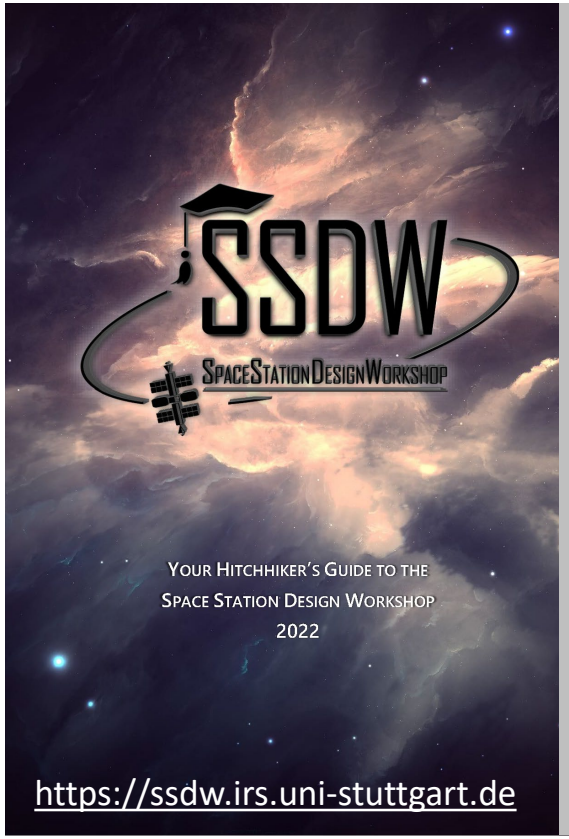
How can we identify and recruit more »Naturals« early in their career?
For finding young talent, academia seems promising …

*) Term borrowed from Mick Herron's seminal series of spy novels, entitled *Slough House*, now adapted for television (2022)
https://9to5mac.com/2022/03/31/slow-horses-spy-series-debuts-on-apple-tv-starring-gary-oldman/

Educating

This section describes recent activities to attract new talent from academia.
Since 2017, PRICE Systems Germany has been supporting the Space Station Design Workshop (SSDW) at the University of Stuttgart.

To find new talent, the Space Station Design Workshop (SSDW) looks promising



- Hosted by the Institute of Space Systems, University of Stuttgart
- Duration one week
- 2 Teams, (Red & Blue), 20 members each
- According to the mission statement, each team shall design a space station and produce a full project report
- Team rooms are set up as concurrent design facility (CDF)
- Each participant is assigned his or her own position in the CDF
- Support comes from a network of experts representing different disciplines
- The experts provide how-to guides and recipes to their CDF counterparts, give lectures on the first two days
- Otherwise, experts support workshop participants 24/7, normally on-site
- SSDW applies typical project phasing: Mission Definition Review (MDR) → System Concepts Review (SCR) → Preliminary Design Review (PDR)
- After submission of final reports, the experts judge each team's results and pick the winning space station design
- Finally, the teams present their results in a public session, followed by a closing dinner

- The SSDW mission statement changes every year, reflecting policy changes in human space exploration
- SSDW methodology, tools and procedures have been refined over more than 25 years
- The aim has always been to stimulate creative solutions from the next generation of space experts!

The team structure in a CDF setup addresses many different skills and talents

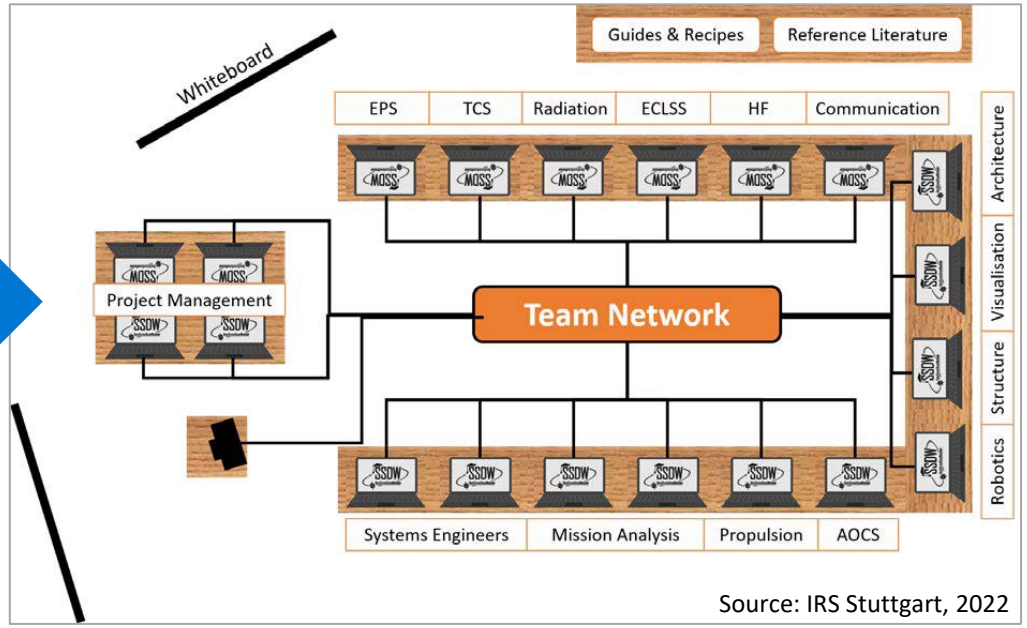
EXAMPLE

PARTICIPANTS – TEAM RED

Name		Position
Anna Helene	***	Architecture
Juan Manuel	***	Communication
Conall	***	**Cost & Risk**
Sophiat	***	Public Relations & Outreach
Michele	***	Power
Lina	***	Human Factors & Life Support
Yakov	***	ISMA – Extraction / Processing
Maximilian	***	ISMA – Processing / Assembly
Isabel	***	ISMA – Robotics / Application
Andrea	***	ISMA – Transport / Manufacturing
Sven	***	Legal
Judith	***	**Project Management**
Daniel	***	Mission Analysis
Zoe	***	Mission Analysis
Daniel Cantos	***	Propulsion & Transport
Patrick	***	Radiation
Nadim	***	Robotics & Maintenance Systems
Ines Filipa	***	Systems Engineering
Thimothée	***	Systems Engineering
Rowida	***	Thermal Control

Source: IRS Stuttgart, 2022

20 positions



Source: IRS Stuttgart, 2022

- In SSDW's CDF, many disciplines compete for students' interest, yet most aspire to be Systems Engineer
- Cost Engineering is embedded in Project Management
- During SSDW 2022, PRICE TruePlanning was used as cost estimating tool, supported on-site by two experts

The 2022 SSDW schedule was packed, leading to an intense week of teamwork

Time	Sunday, 24.07.	Monday, 25.07.	Tuesday, 26.07.	Wednesday, 27.07.	Thursday, 28.07.	Friday, 29.07.	Saturday, 30.07.	Time
Topic	Welcome, Introduction, Teambuilding	Top-Level Lectures & Mission Definition	Requirements and Systems Engineering	Systems and Subsystems Engineering	Subsystems Engineering, Documentation	Documentation	Final Presentation, Evaluation, Closing Dinner	Topic
08:30 08:45		**Intro to SSDW-Toolkit**	**Valispace** **Propulsion** **Thermal Control** **Robotics & Mechanism** **EPS** **Transportation**	Team Exchange	Team Exchange	Team Exchange	Presentation Preparation	08:30 08:45
09:00 09:15 09:30 09:45		**Project Management** **Systems Engineering** **Cost & Risk**		Team Work Systems and Subsystems Engineering	Team Work Subsystems Engineering	Team Work Final Engineering		**09:00** 09:15 09:30 09:45
10:00 10:15	Welcome reception		Coffee Break	Coffee Break	Coffee Break	Coffee Break	**Final Pres. Delivery**	**10:00** 10:15
10:30 10:45	**SSDW**	Coffee Break	**LSS** **Human Factors** **Communication** **Radiation** (order to be confirmed)	Team Work Systems and Subsystems Engineering	Team Work Subsystems Engineering	Team Work Documentation	Breakfast Break	10:30 10:45
11:00 11:15	**IRS + Student Groups**	**SSDW Task**					**Public Presentations**	**11:00** 11:15
11:30 11:45	**Sponsors**	**ISRU + ISMA** **Space Law** **Mission Analysis**	Team Work Requirements and Initial System Engineering					11:30 11:45
12:00 12:15 12:30 12:45	Lunch Break	Lunch Break	Lunch Break	Lunch Break	Lunch Break	Lunch Break	Coffee Break	**12:00** 12:15 12:30 12:45
13:00 13:15 13:30 13:45	SSDW participants presentations	Team Work Requirements Engineering	Team Work Requirements and Initial System Engineering	Team Work Systems and Subsystems Engineering	Team Work Subsystems Engineering	Documentation	Get Together	**13:00** 13:15 13:30 13:45
14:00 14:15 14:30 14:45								**14:00** 14:15 14:30 14:45
15:00 15:15 15:30 15:45	Coffee Break							**15:00** 15:15 15:30 15:45
16:00 16:15 16:30 16:45	**Team Challenge**	Coffee Break Team Work Requirements Engineering	Coffee Break Team Work Requirements and Initial System Engineering	Coffee Break Team Work Systems and Subsystems Engineering	Coffee Break Team Work Subsystems Engineering	Coffee Break Documentation		**16:00** 16:15 16:30 16:45
17:00 17:15 17:30 17:45		**Deliverables**	**Deliverables**		**Preliminary Design Review**			**17:00** 17:15 17:30 17:45
18:00 18:15 18:30 18:45	Get-Together	**Mission Definition Review**	**System Concepts Review**			**Final Report Delivery** Presentation Preparation	Closing Dinner Höhencafe Killesberg	**18:00** 18:15 18:30 18:45
19:00 19:15 19:30 19:45	Space Night Planetarium Stuttgart	Dinner Event Brauhaus Schonbuch	Dinner Event Joe Penas		**Mystery Meeting** Final Engineering (all night long)	Free Evening		**19:00** 19:15 19:30 19:45
20:00 20:15								**20:00** 20:15

Lectures	Groupwork Team Design Rooms 0.49/2 and Boysen	Social Events	Public Events	Reviews & Deadlines

Picture: Team Blue in their CDF two hours before final report delivery deadline on 29 July 2022 (author)

SSDW 2022 Cost Engineering Questionnaire

Dear SSDW participant,

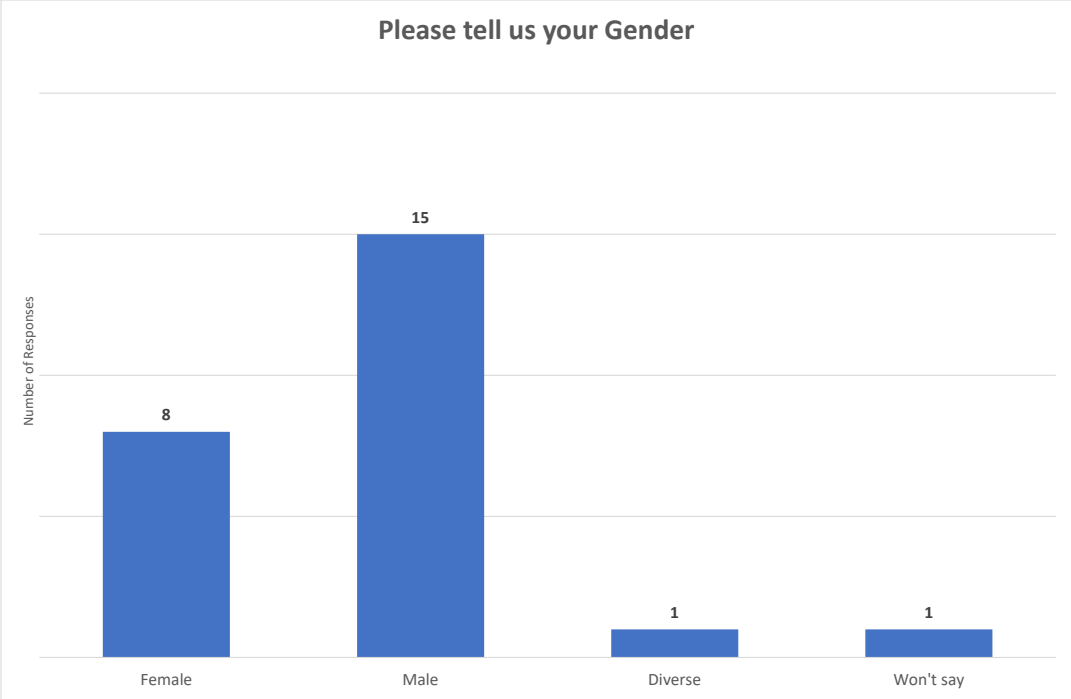
we thank you for your dedication and the hard work you invested into the outcomes of SSDW 2022.

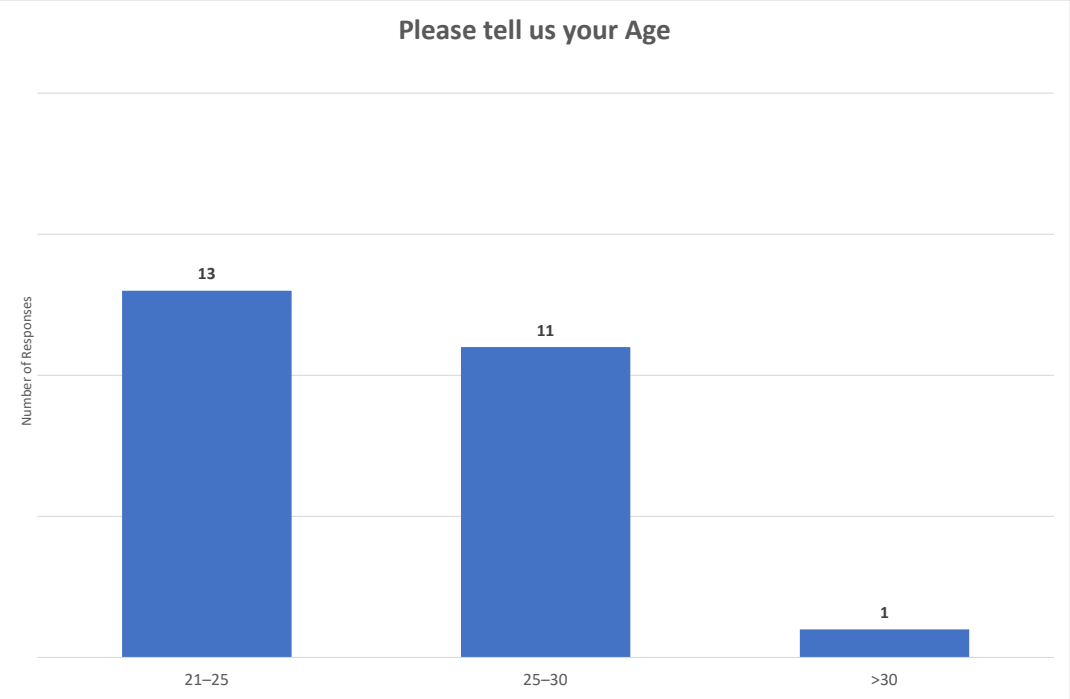
Before you leave, we kindly ask you a favour and invite you to fill out the following short questionnaire. It will help us to better understand how to attract young talent like you to a career in Cost Engineering.

Many thanks in advance,
-Your Cost Experts from SSDW 2022

All participants were invited to take part in a survey; its aim was to better understand what might attract them to a career in Cost Engineering

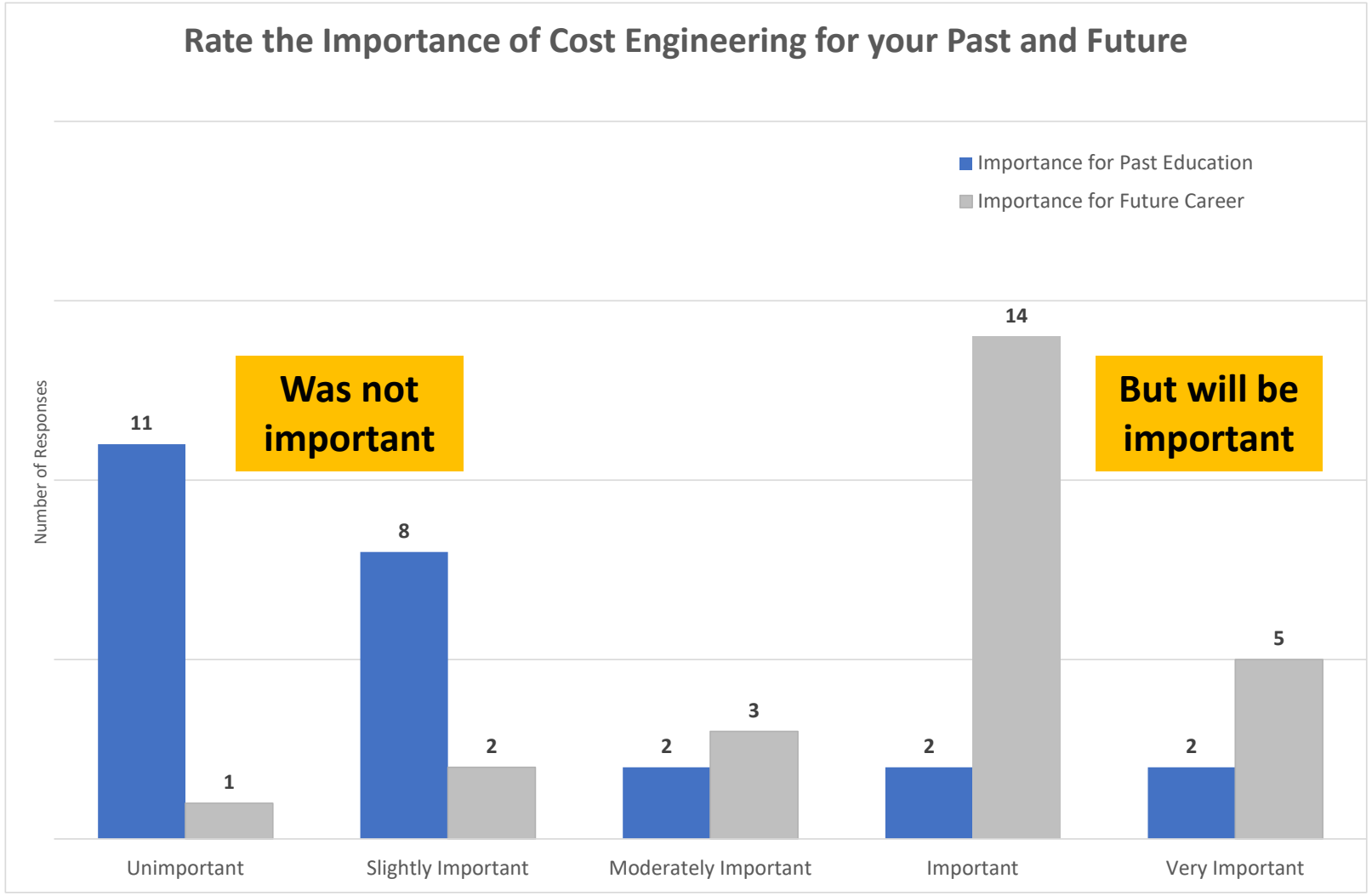
25 out of 40 participants from SSDW 2022 were willing to take part in the survey





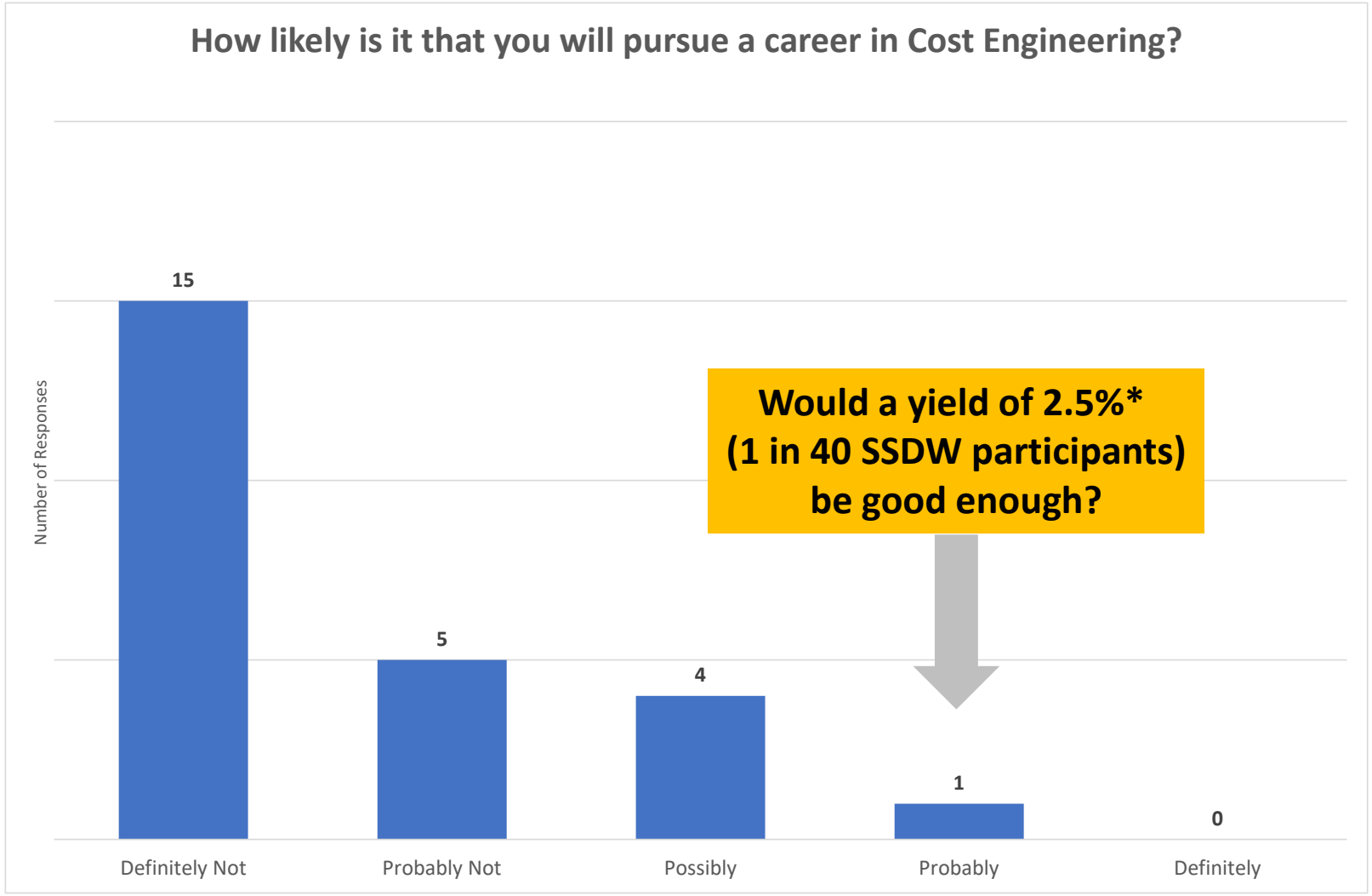
- 63% participated in the survey on Cost Engineering (25 out of 40)
- 60% of respondents are male, close to their percentage in total SSDW group (15 out of 25)
- 52% of respondents are 21–25 years old (13 out of 25)

Cost Engineering will become much more important for future careers



- 76% (4 out of 25) say that cost engineering was **unimportant** or only **slightly important** for their past education
- The same number, 76% (19 out of 25), state that it will be **important** or even **very important** for their future career!
- **This might point to deficits in higher education**

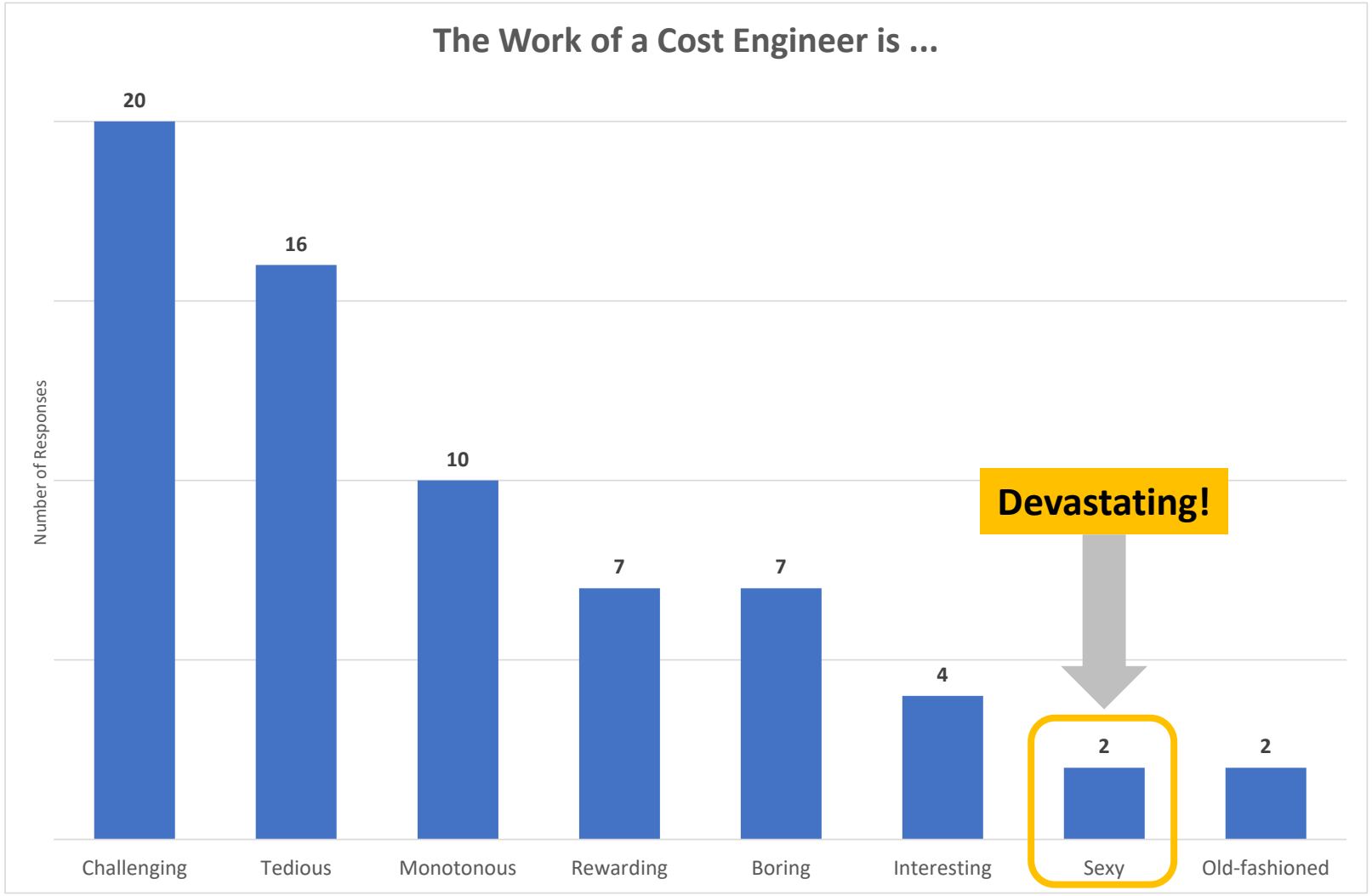
Almost nobody wants to pursue a career in Cost Engineering!



- Keeping in mind that 76% deem cost engineering **important** or even **very important** for their future career, it comes as a surprise that 80% will **probably not** or **definitely not** want to become a cost engineer!
- **Only 4% (1 out of 25) will probably pursue a career in the field!**

*) Assuming that all non-respondents will definitely not pursue a career in cost engineering

Cost Engineer is not a sexy job! Unlike Data Scientist.



Data Scientist: The Sexiest Job of the 21st Century

Meet the people who can coax treasure out of messy, unstructured data. by Thomas H. Davenport and DJ Patil

From the Magazine (October 2012)

Andrew J Bulbolz, silk screen on a page from a high school yearbook, 8.5" x 11", 2011 Tamar Cohen

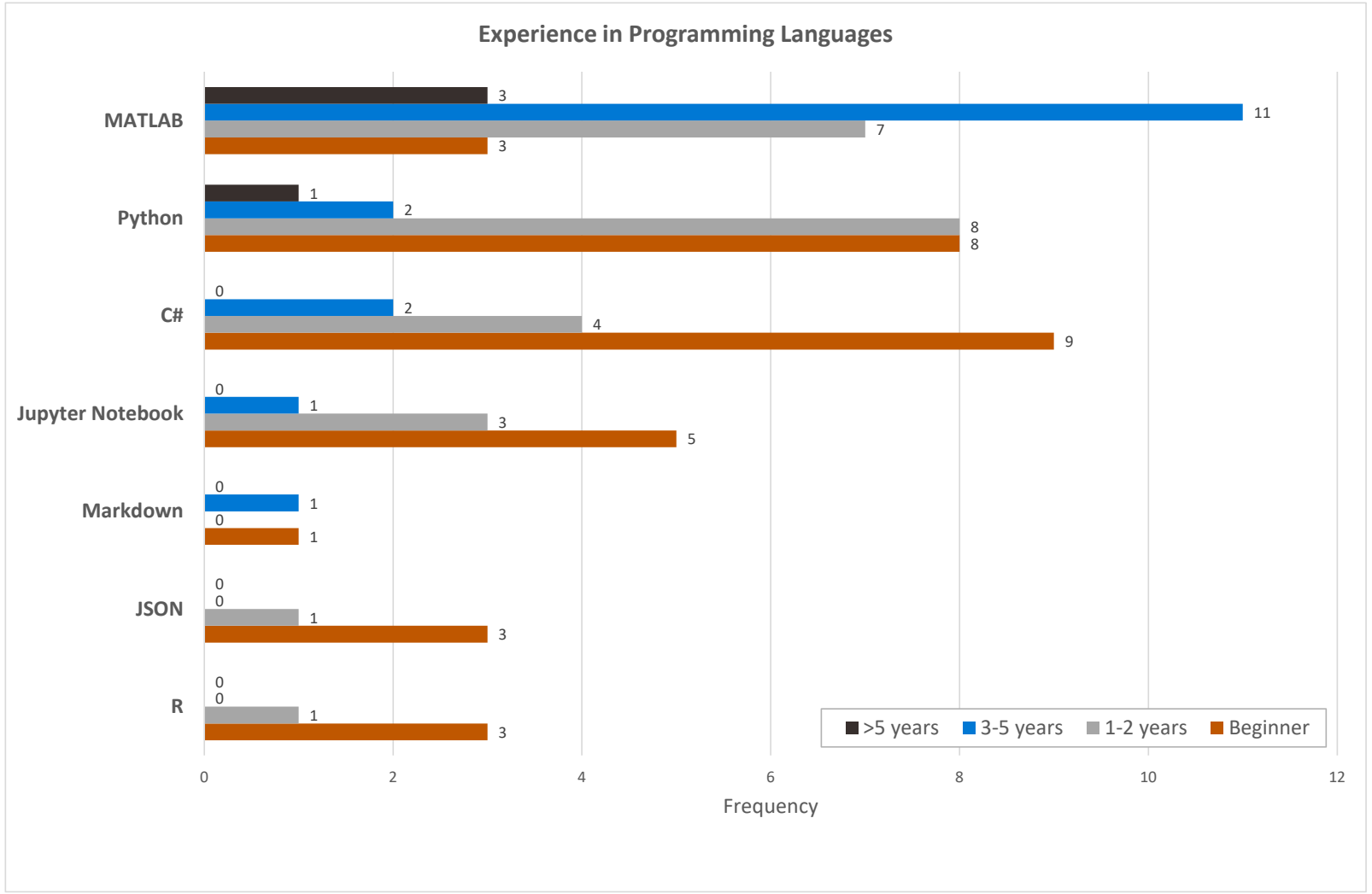
Summary. Back in the 1990s, computer engineer and Wall Street "quant" were the hot occupations in business. Today data scientists are the hires firms are competing to make. As companies wrestle with unprecedented volumes and types of information, demand for... more

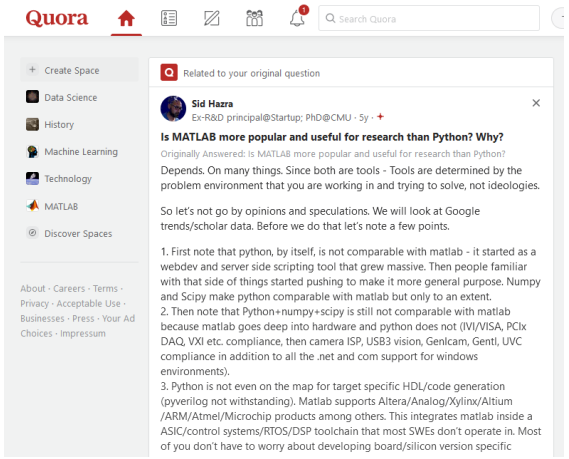
When Jonathan Goldman arrived for work in June 2006 at LinkedIn, the business networking site, the place still felt like a start-up. The company had just under 8 million accounts, and the number was growing quickly as existing members invited their friends and colleagues to join. But users weren't seeking out connections with the people who were already on the site at the rate executives had expected. Something was apparently missing in the social experience. As one LinkedIn manager put it, "It was like arriving at a conference reception and realizing you don't know anyone. So you just stand in the corner sipping your drink—and you probably leave early."

https://hbr.org/2012/10/data-scientist-the-sexiest-job-of-the-21st-century

→ Only **2 out of 25** find the work of a cost engineer "sexy"

SSDW participants are not very experienced in data science tools

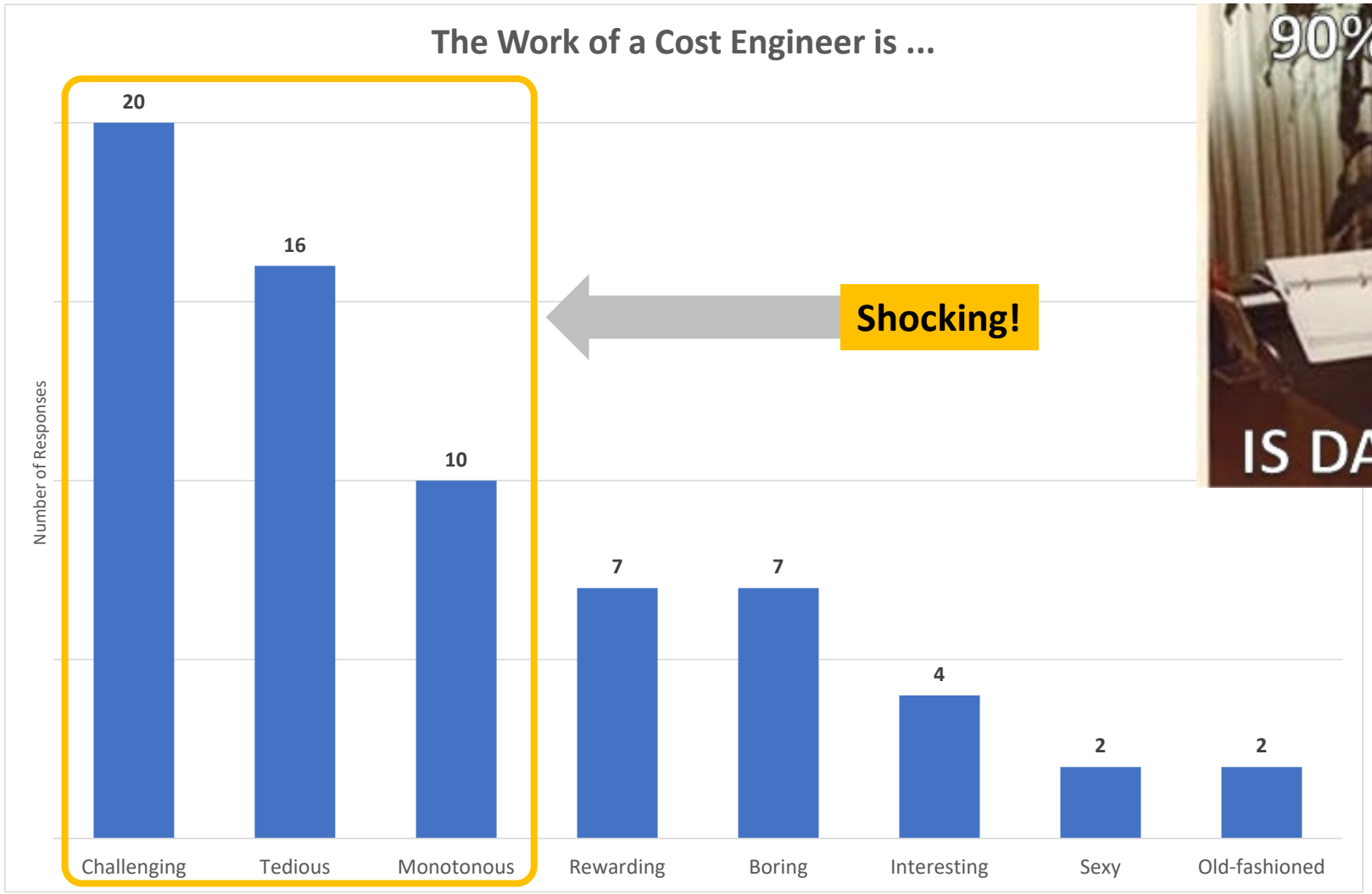




https://www.quora.com/Is-MATLAB-more-popular-and-useful-for-research-than-Python-Why

SSDW participants are not data scientists. MATLAB is the most used programming language among respondents.

Data Collection seems to make the Cost Engineer's job unattractive



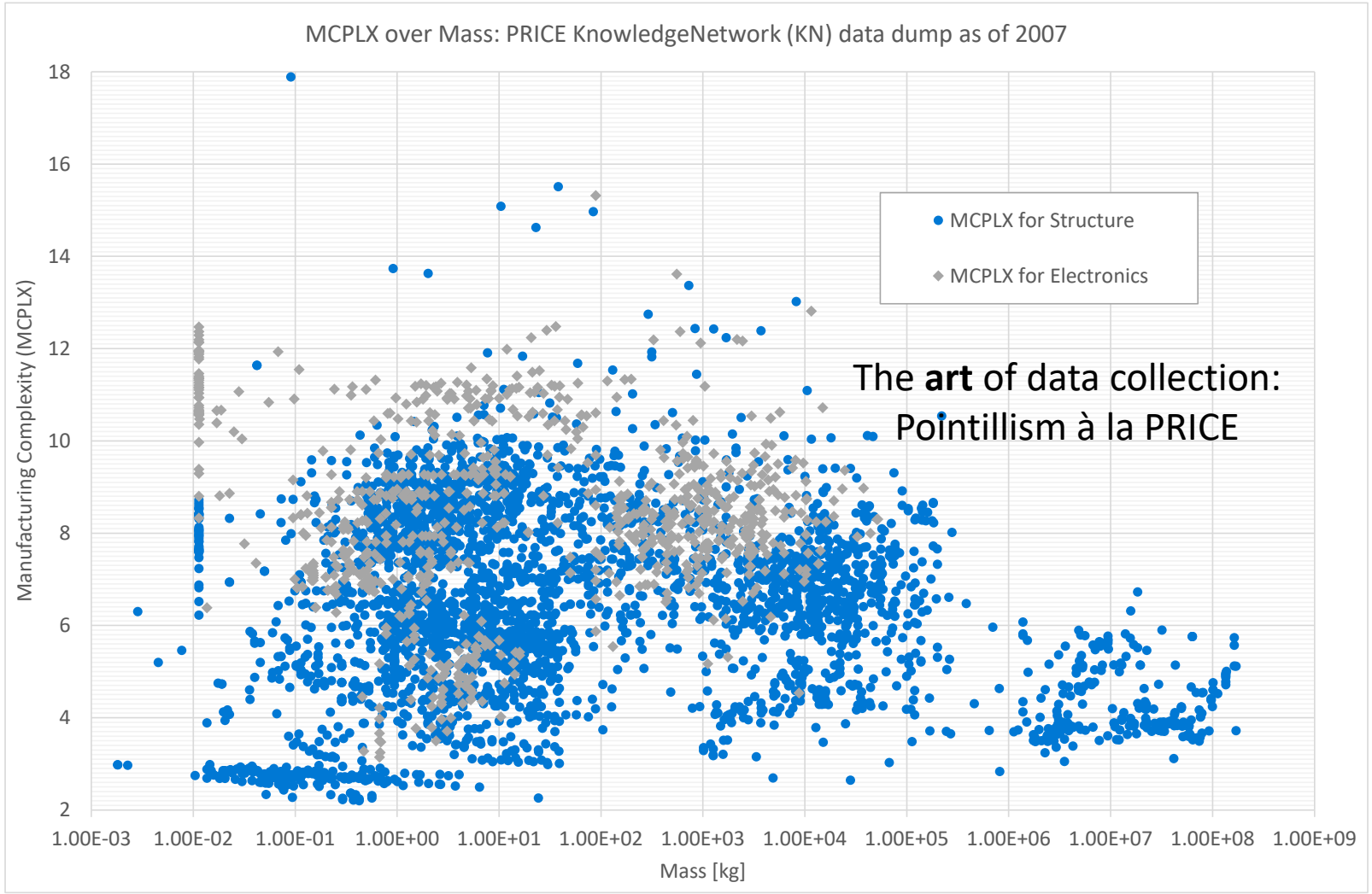
Frank Freiman, inventor of parametrics, c1975

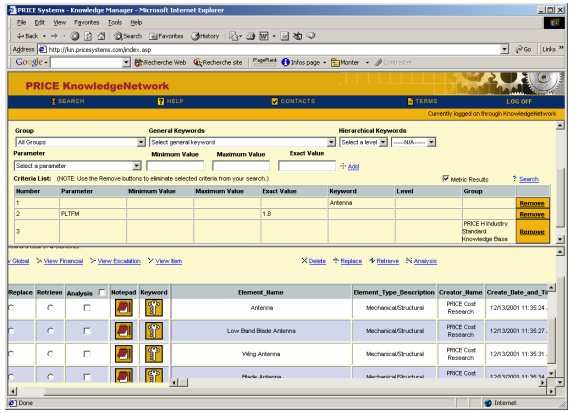
Is the **challenging, tedious, monotonous** collection of input data the reason why so few want to become a cost engineer?

The Science and Art

The next section covers a key issue as seen by SSDW participants, namely: how to improve data collection.

Calibrated MCPLX data shall provide input guidance and make users happy: In the past, there was KnowledgeNetwork (KN)



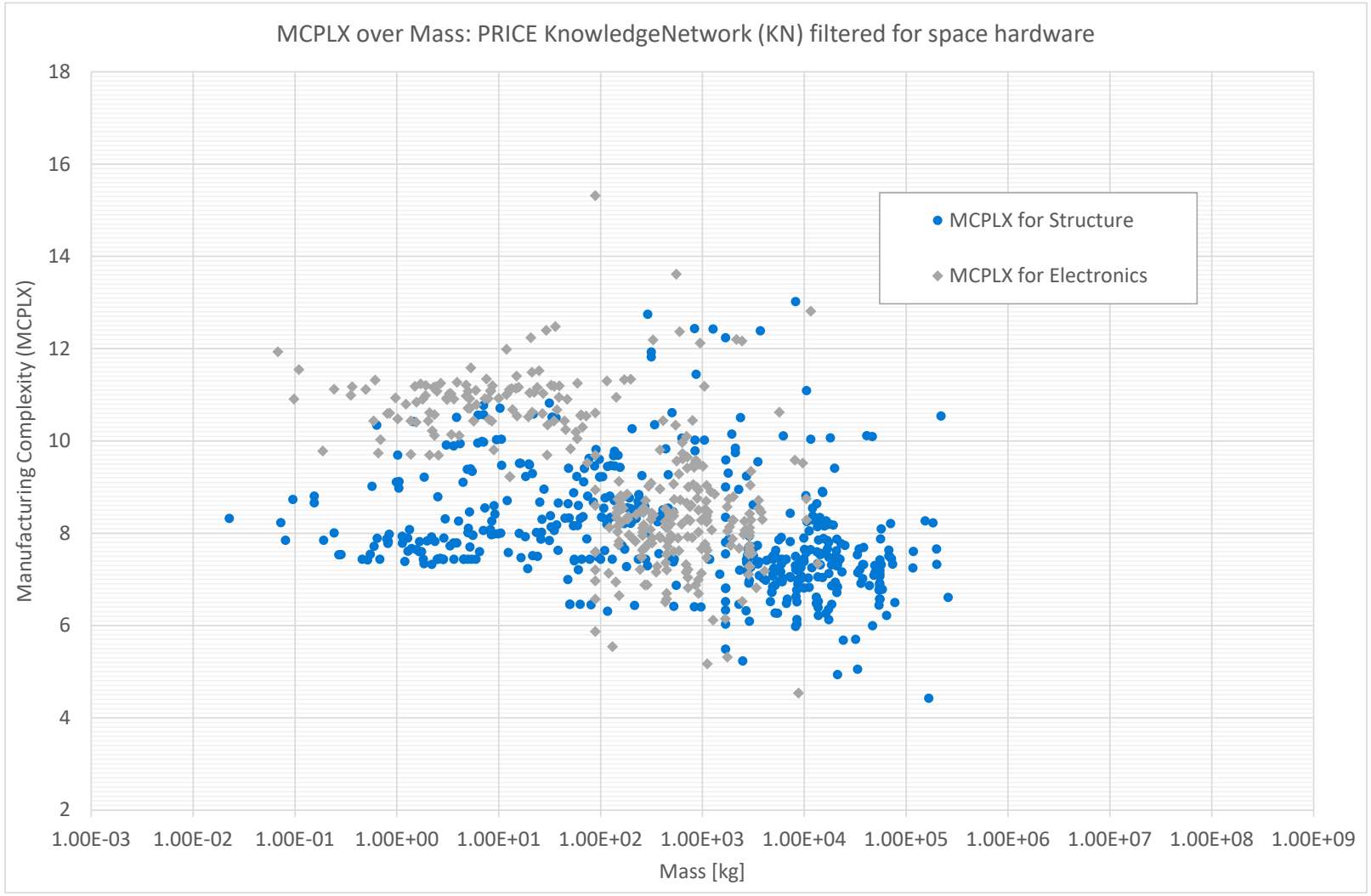


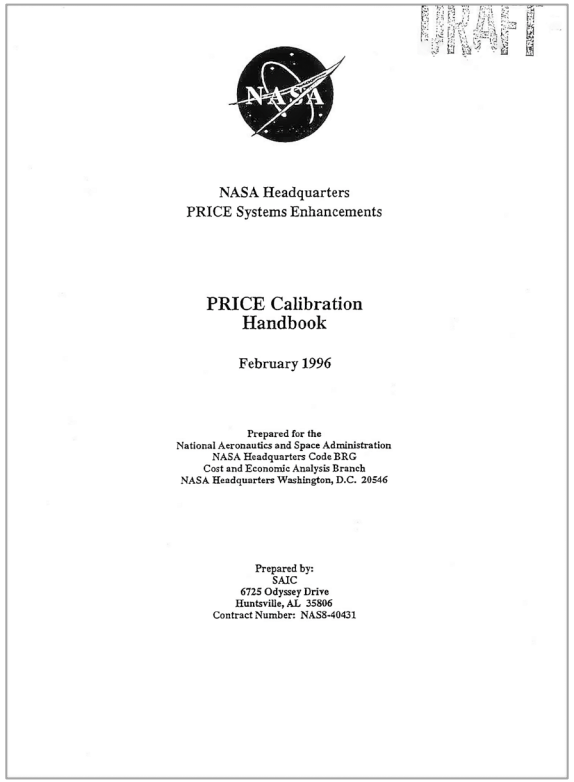
KnowledgeNetwork™ was a cost knowledge base hosted on the PRICE website

It contained typical inputs for cost estimates

Discontinued in 2014, it was replaced by TruePlanning's built-in equipment type calculator

When filtering KnowledgeNetwork for space hardware, few data points remain




DRAFT

NASA Headquarters
PRICE Systems Enhancements

PRICE Calibration Handbook

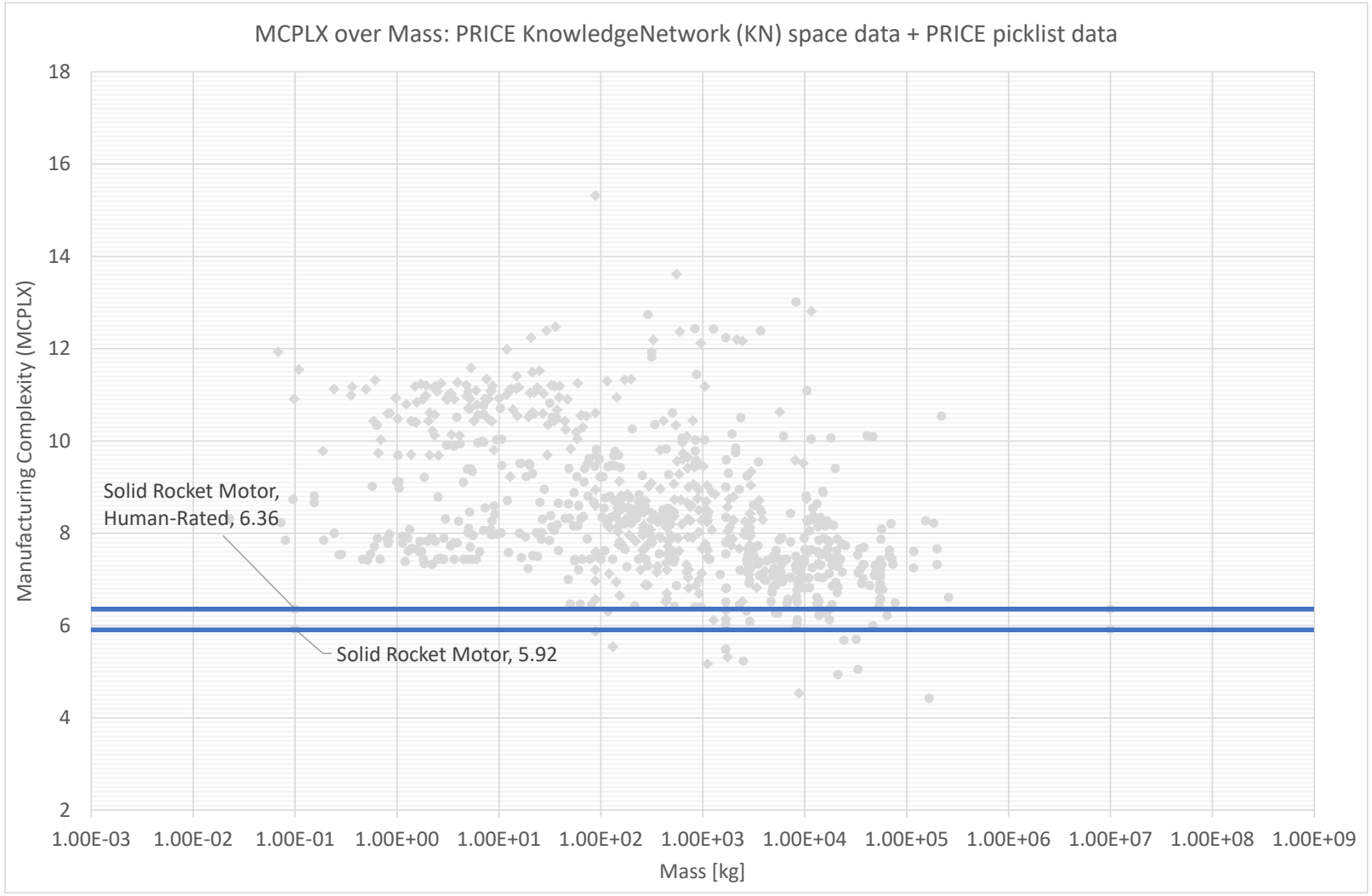
February 1996

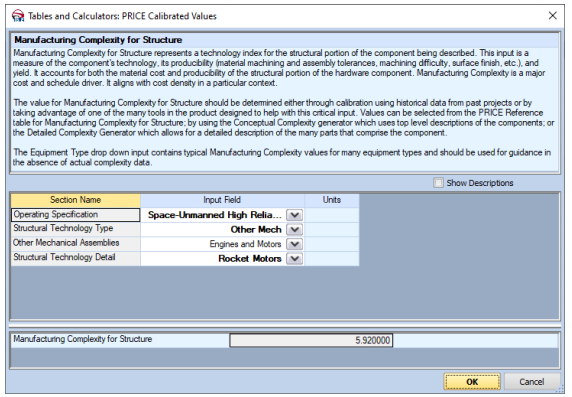
Prepared for the
National Aeronautics and Space Administration
NASA Headquarters Code BRG
Cost and Economic Analysis Branch
NASA Headquarters Washington, D.C. 20546

Prepared by:
SAIC
6725 Odyssey Drive
Huntsville, AL 35806
Contract Number: NAS8-40431

Most data points on the left came from NASA's 1996 PRICE Calibration Handbook

There are virtually no space-specific PRICE calibrated values in picklists

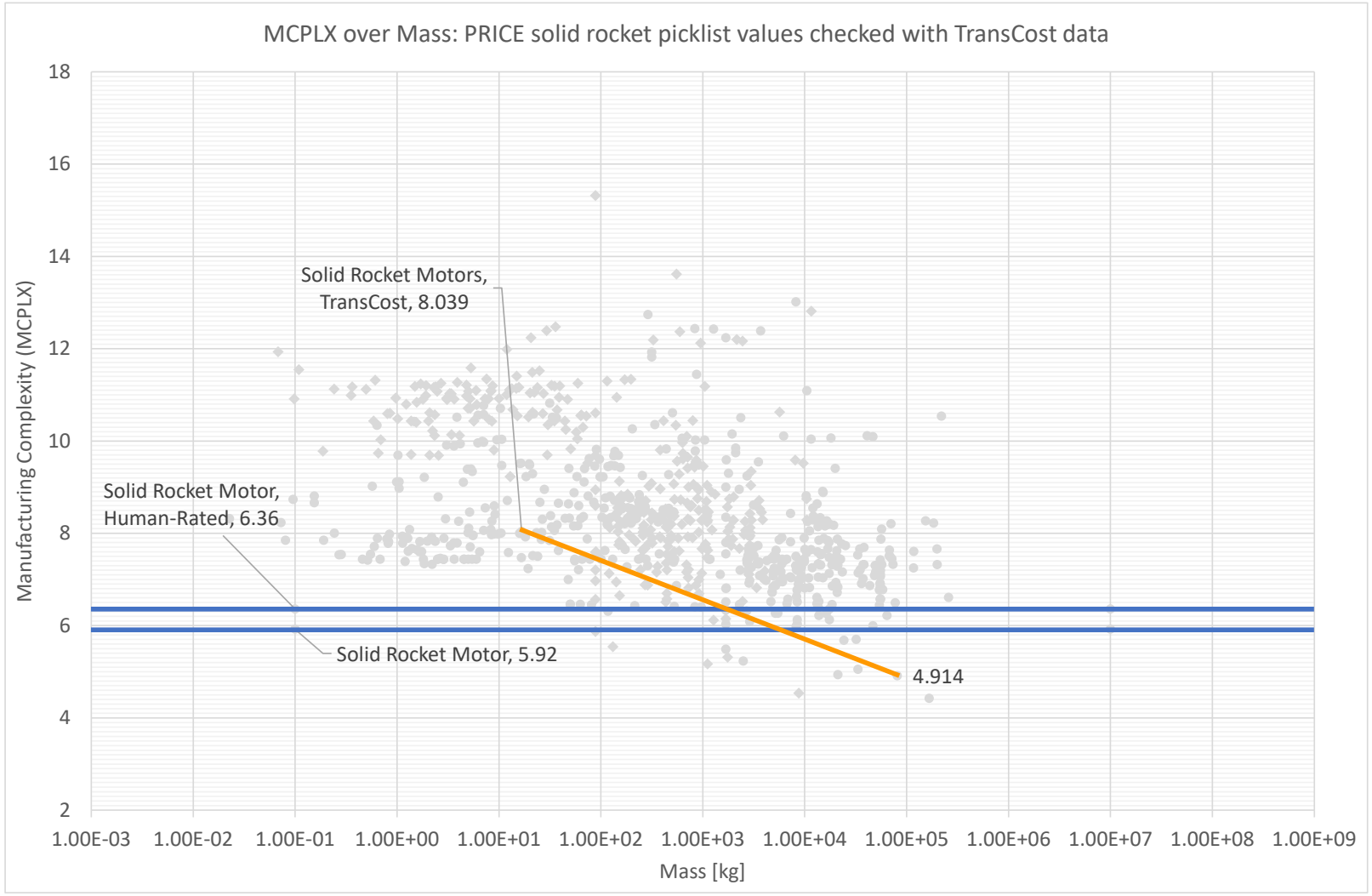


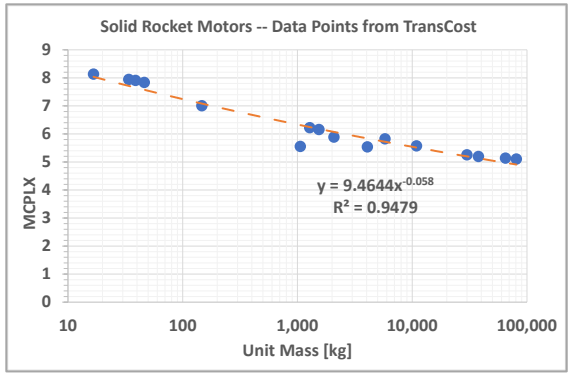


General cost models like PRICE are based on the hypothesis that the MCPLX exponent is the same for all members of a product family.

See example on left: (Solid) Rocket Motors.

The need to supply SSDW teams with more calibrated data points led to the idea to map data from other cost models, like TransCost



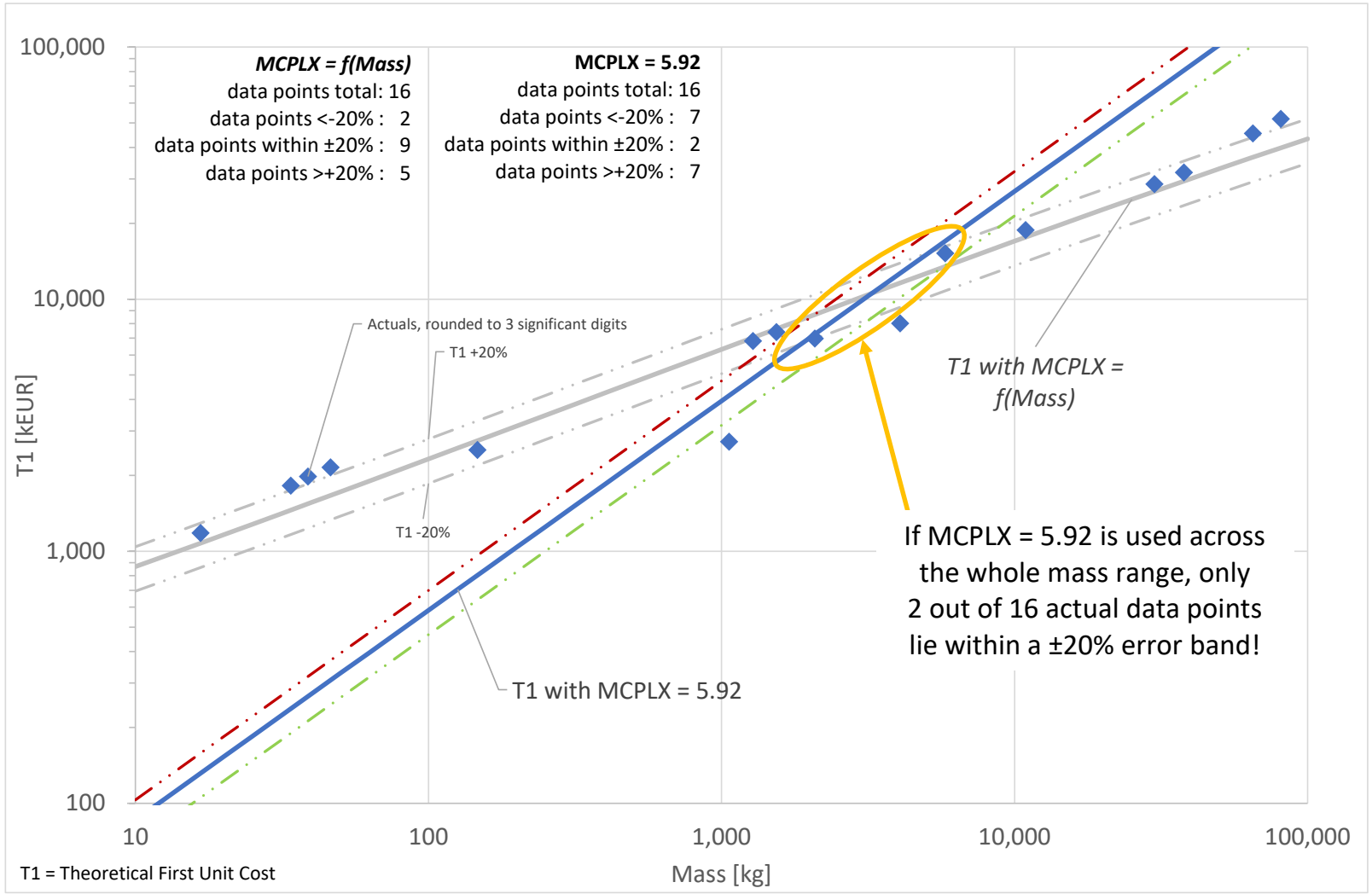


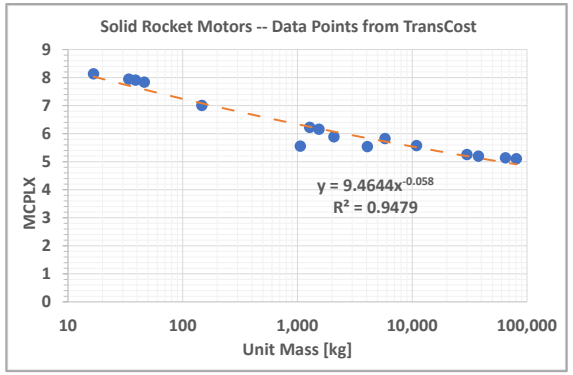
The TransCost model offers many data points

They can be mapped in TruePlanning, see the solid rocket motors example on the left

The example shows that MCPLX is <u>not</u> independent from Mass

The solid rocket motor example shows: Fitting the TransCost T1 cost curve within ±20% error bands at a constant MCPLX does not work



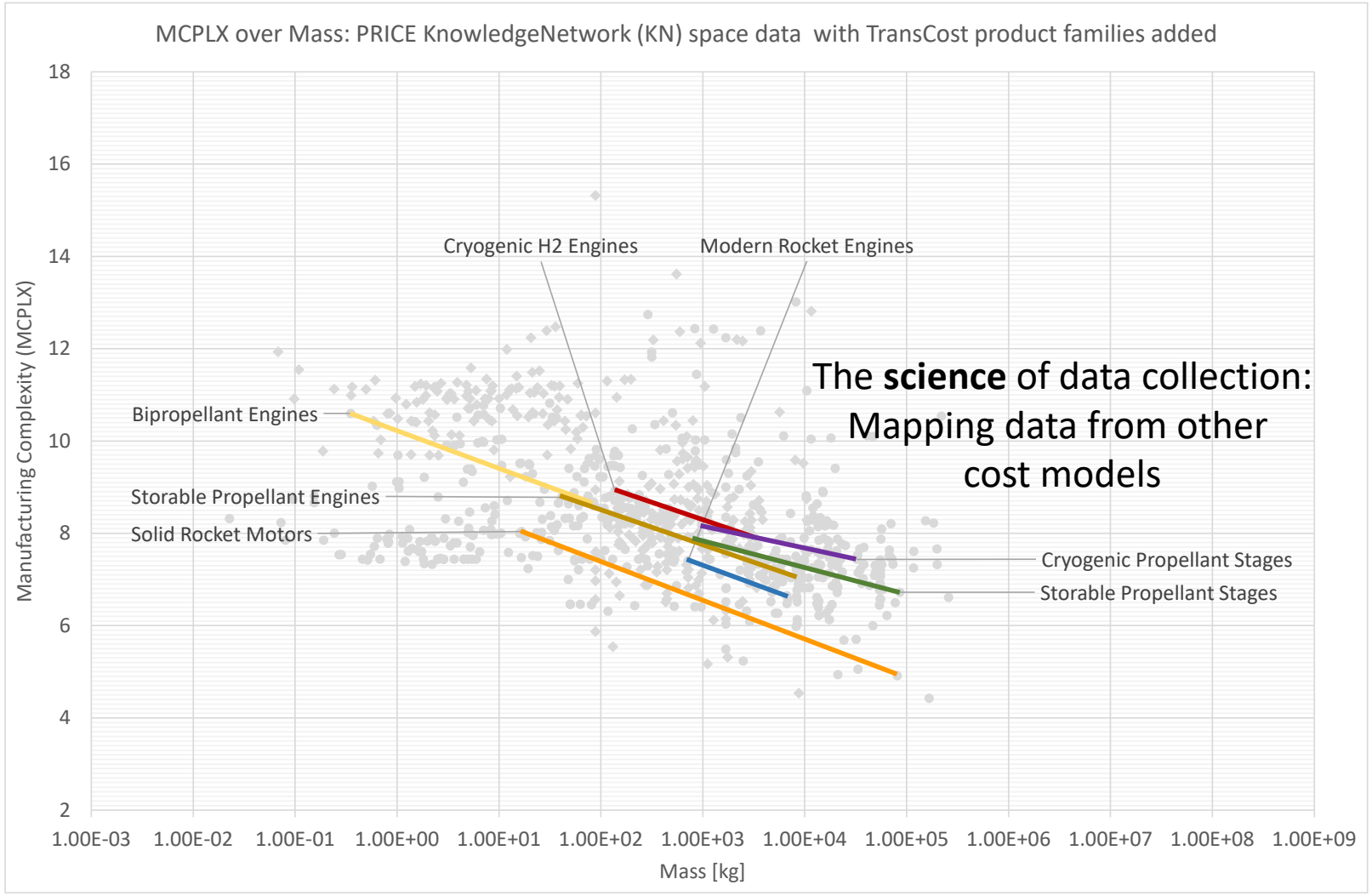


In TruePlanning, slope and intercept of a CER are coupled via MCPLX

Changing slope will change intercept, and vice versa

The best fit curve to the T1 actuals (see left) can only be achieved with a variable MCPLX = *f*(Mass)

Other TransCost product family data can be mapped to PRICE TruePlanning; but there is no way to hold MCPLX constant



SSDW "trainees" loved examples in the form of reference data, the more, the better.

TransCost was used as data source for calibration. 7 product families (see left) were investigated.

When mapping TransCost to PRICE TruePlanning, <u>all</u> TransCost product families will show variable MCPLX as function of mass!

This approach could be extended to include further cost models, like AMCM or NAFCOM.

Conclusion

This final section covers what we have learned so far from supporting the Space Station Design Workshop (SSDW) and what shall be the next steps on our quest for new cost engineering talent.

Over five years of supporting SSDW, we have learnt some lessons

Typical participants are students; so, **we meet and train potential candidates before they enter the job market**; everybody seems highly motivated and eager to learn; these are fantastic circumstances for scouting young talent	**Target Group**
One week in **a Concurrent Design Facility (CDF) is the perfect environment to assess trainees**; you spend one week together, almost 24/7, with people engaged in an actual project, deliverables and all; there simply is no better way	**Training Environment**
In the pecking order within SSDW teams, the Cost Engineer is near the bottom; the current data science hype does not seem to impact interest in cost engineering; **everybody finds the job important, but 96% want somebody else to do it!**	**Job Appeal**
The SSDW CDF does not need a particular brand of cost model to work properly; however, since 2019, PRICE TruePlanning has been used as primary cost tool (sponsored); it is feature-rich and allows to easily map data from diverse sources	**Cost Models**
Collecting data is the biggest challenge for participants; mapping data points from different cost models and other sources can help; highest on the wish list is a (tbd) **Calibration Handbook** covering current space systems, subsystems and equipment	**Data Collection**

All stakeholders can support the quest for new cost engineering talent

Agencies & Government shall …

- … endorse an open exchange of cost data
- … acknowledge the need for specific “cost engineer” job profiles in different domains (automotive vs. aerospace; industry vs. agency; early phase studies vs. production improvement)

Industry shall …

- … convey a positive image of jobs in cost engineering
- … support hands-on activities in academia (like SSDW) with expert knowledge
- … publish more data, if needed as minimum viable datasets (MVD) that describe product families without disclosing confidential data points

Tool Vendors shall …

- … test product families for independence (orthogonality) of mass and exponent (MCPLX)
- … compile a calibration handbook comprising open-source data points for all kinds of space systems, subsystems, and equipment
- … support academia with lectures and expertise

Academia shall …

- … offer more courses on cost engineering
- … embrace concurrent design facility (CDF) format for student projects like SSDW
- … mandate cost estimates for all student projects
- … seek cooperation with professional organizations like ICEAA (International Cost Estimating and Analysis Association)

Thank you!

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Backup Slides

The next pages offer some additional slides for detailed discussion, if needed.

Experts provide guides and recipes to SSDW participants

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1 Cost and Risk Management

1.1 Motivation

For human spaceflight, good cost estimating is a critical ingredient of a well-run project. During every project phase, systems and design engineers need to provide timely cost information together with the technical attributes of mission design. No longer can programs leave cost estimates as an afterthought for a separate cost analysis team. In modern projects, cost engineers are now embedded in concurrent design teams from the beginning. Whenever design changes occur, the cost experts can rapidly analyse the impact on life cycle costs, leading to better decisions, sooner than before.

The major life cycle cost drivers are:

- Design and development of new hard- and software
- Manufacturing and testing (for space qualification!) of system elements
- Launches for on-orbit assembly
- Launches for logistics, support, and crew rotation
- Ground personnel for operations

To obtain a first cost estimate of your space station design, follow the steps of this recipe and use as many sources for data input as possible. Finally, stay in contact with all relevant design team members.

Remember to consider design margins according to Recipe "Design Margins".

1.2 General Rules for Cost Reduction

The following points have been established as "best practices" over 60+ years of spaceflight:

- Minimize the number of launches.
- Minimize time to "assembly complete".
- Utilize existing hardware, technologies, and designs, whenever possible.
- Minimize the operational and logistical effort during assembly and normal operation.
- Use commercialization opportunities to create additional income or share cost.

Discuss these topics with your team members from the other subgroups!

EXAMPLE

Recipe: Introduction

1.3 Cost Estimating Process

Step	Tasks	What to use	Remarks
1	Obtain Work Breakdown Structure (WBS) of your mission	Ask your design team	
2	Define the level of the cost estimate	Given by Mission Statement	
3	Define the scope of the cost estimate	Given by Mission Statement	
4	Collect information on the baseline mission	Ask your design team	
5	If different alternatives come up, collect input data needed for trade studies	Ask your design team	See step #16
6	Establish estimation ground rules and assumptions, document those in master data and assumptions list (MDAL)	Checklist provided with this recipe	Document properly, you will be asked about it
7	Categorize WBS elements into 'make' and 'buy' items	Ask your design team	Use 'buy' items wherever possible
8	For all 'make' elements, define the quantity needed, including prototypes	Document in an MS Excel® scratchbook	
9	For 'buy' items, use publicly available information on purchase cost, apply overhead and handling fees	Document in an MS Excel® scratchbook	
10	Define wherever assembly, integration, test (AIT) takes place	Refer to Table 29-5 in HSMAD Chapter 9, see PDF file	
11	Document all collected input data for your final report	PRICE TruePlanning	
12	Consolidate all WBS elements in one TruePlanning file, do the cost estimate for total cost, broken down by WBS element	PRICE TruePlanning	
13	For those elements with more than 1 design option, compare costs of alternative concepts and pick the best option	PRICE TruePlanning	Document the reasons for selecting best option
14	Review results with your team, apply cost adjustments if needed		Document reasoning for adjustment
15	Spread mission cost estimate over the program life, using constant-year dollars (July 2018)	MS Excel® scratchbook	
16	Determine the major drivers of mission costs for potential cost reductions		
17	Quantify cost model input parameter uncertainty; define input distribution functions for relevant parameters	PRICE TruePlanning	3-point (pessimistic, point, optimistic) is sufficient
18	Test the sensitivity of lifecycle costs to cost model input parameter uncertainty, key assumptions and requirements	PRICE TruePlanning	
19	Define risk register with probability of occurrence, schedule and cost impacts	Document in an MS Excel® scratchbook	
20	Describe technical risk coming from external project risks,	Document in an MS Excel® scratchbook	
21	Test the sensitivity of lifecycle costs to occurrence of external risks	You may use @RISK (trial version http://www.palisade.com/trials.asp)	This is a 'stretch goal'
22	Formulate recommendations for project implementation		

EXAMPLE

Process Description

1.4 Cost Estimating Input Checklist

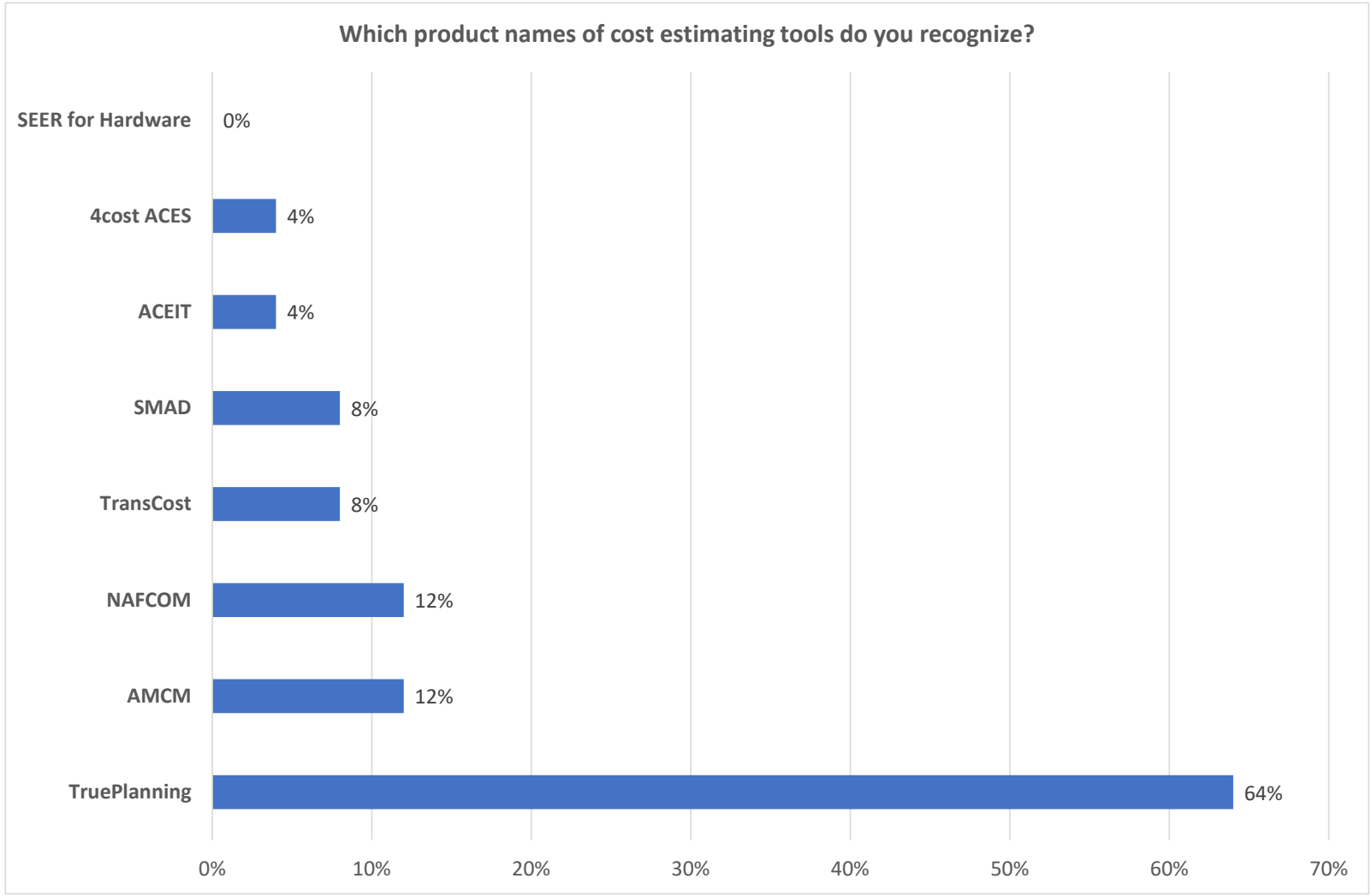
Information Required	Ground Rule or Assumption	OK?
Currency and escalation used	**Dollar or Euro, constant (given)** **Economic Base Year: 2022 (given)**	□ □
Schedule information, start and end dates, milestones	Phase B Authorization to Proceed (ATP) Phase C/D ATP First Flight Initial Operating Capability (IOC) Time horizon tor lifecycle cost computation	□ □ □ □ □
Quantities	Number of Prototypes (based on model philosophy) Number of Production Items Number of Spares	□ □ □
Size	Mass (in kg) Volume (in m³, check payload shroud compatibility)	□ □
Design Inheritance	Block number for Prototype(s) Block number for Production Items	□ □
Operating Specification	Ground Infrastructure (1.0) Robotic Elements (2.0) Human-Rated Elements (2.5)	□ □ □
Engineering Complexity	Scope of Design Effort (Simple modification, Existing design … New design, State-of-the-art technology) Experience of Personnel (Extensive experience, Familiar product … Limited experience, Unfamiliar product)	□ □
Industrial Setup	Flow of parts and assemblies through Fabrication, Assembly, Integration, Test (AIT) Profit and Fees (included or not included)	□ □
Operation Cost Drivers	Mission lifetimes Hardware replacement assumptions Launch rates Number of flights Staff size (full-time equivalents (FTE))	□ □ □ □ □
Public-Private Partnership	Government's role in development Government's role in integration and test Government's role in launch procurement Government's role in launcher provisioning Impact of government support on cost etc. …	□ □ □ □ □
Facilities (Ground and Space)	List of facilities used as is List of facilities modified List of new buildings List of new equipment etc.	□ □ □ □ □
Miscellaneous		□ □
Number formatting	s for cost results	□ □

Feel free to amend this checklist if you come across novel issues or items you deem worthy to include.

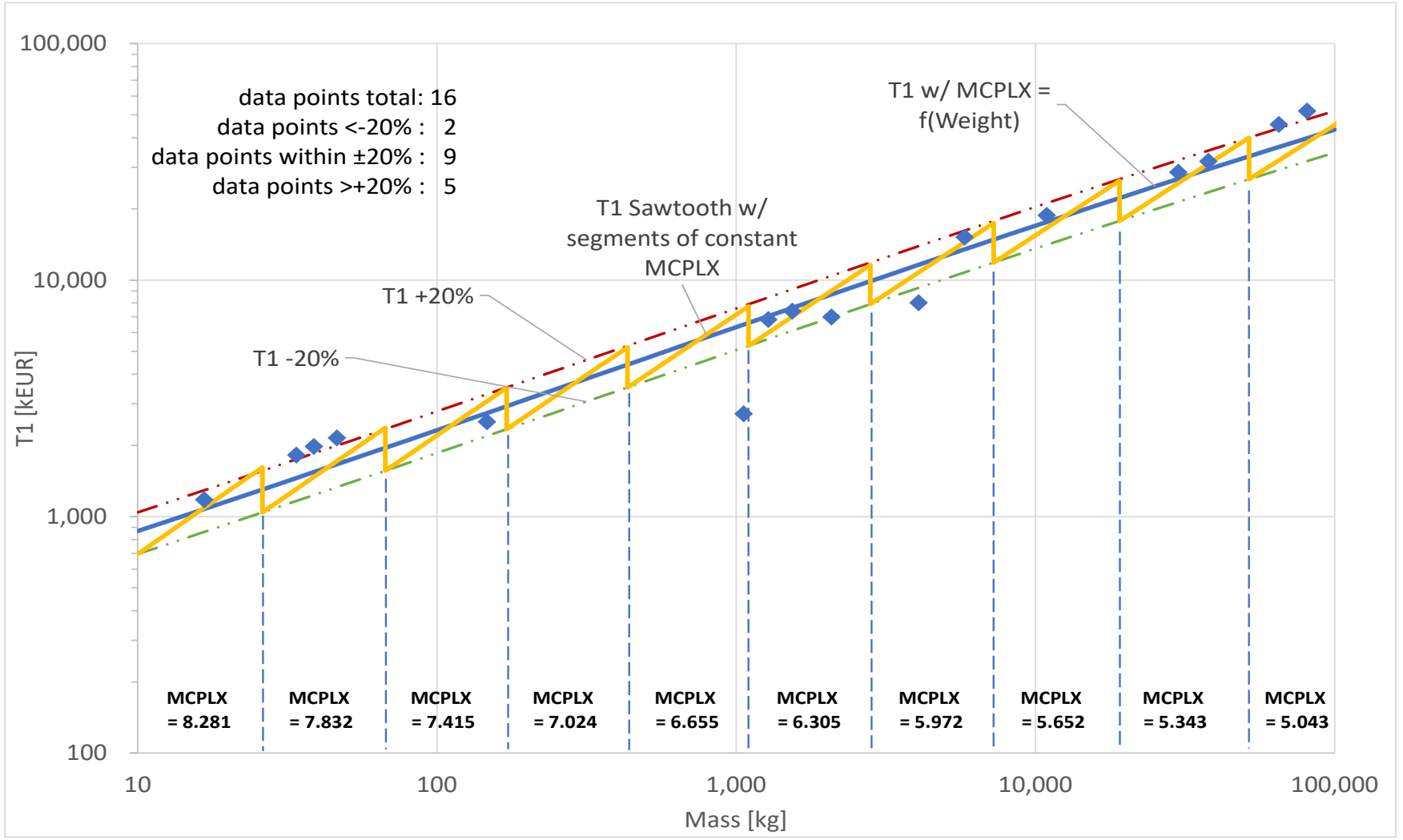
EXAMPLE

Checklist

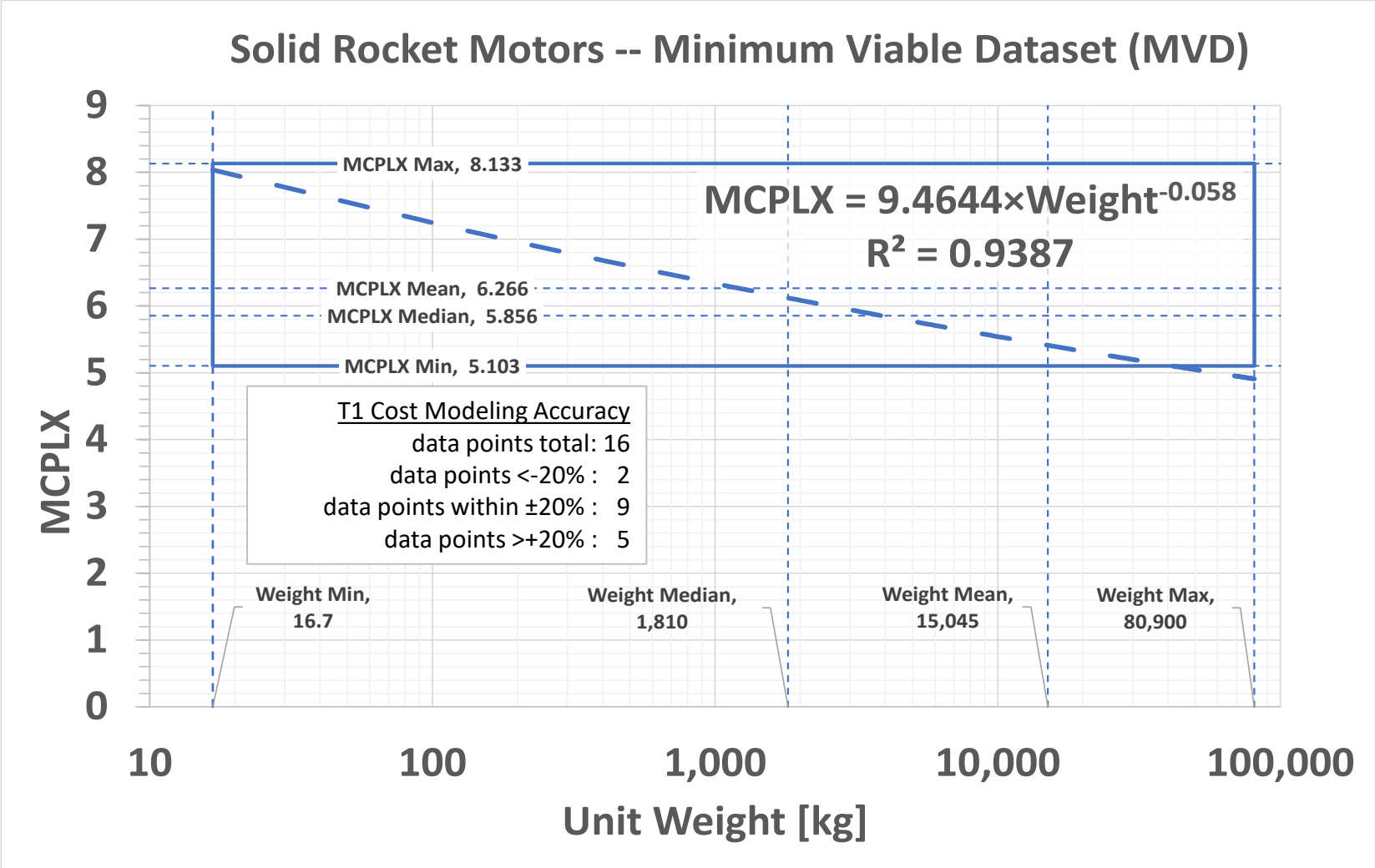
The SSDW 2022 survey asked for name recognition of cost estimating tools



Fitting a T1 curve within ±20% error bands can be done by segmenting MCPLX by mass (Example)



A welcome side effect of mapping product families from other cost models to TruePlanning is the quantification of cost modelling accuracy



A recurring complaint is that cost modeling accuracy for product families is either unknown or missing

By default, neither TruePlanning nor TransCost provide it

The solid rocket motor example on the left shows how it can be done without special tools like TrueFindings

If needed, a product family could be accurately described without having to disclose single data points

Minimum Viable Datasets bridge the gap between full datasets and abstract picklist values

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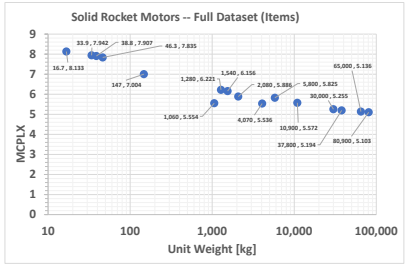
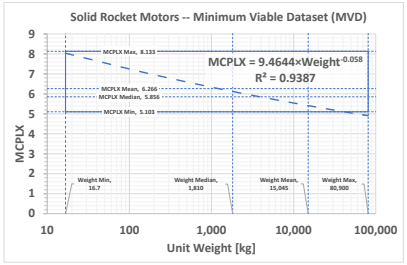
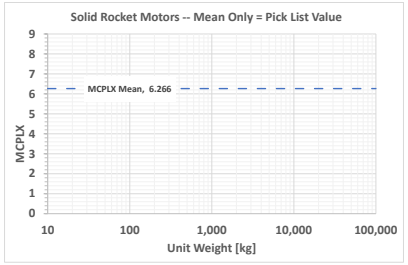
Full Dataset (Single Products)	**Minimum Viable Dataset (Product Family)**	**Picklist Value (Product Family)**
		
Product Family: Solid Rocket Motors **MCPLXS Range = 5.103–8.133** *Weight Range = 16.7–80,900 kg* *Data Points in Total: 16* **Cost Modeling Accuracy:** *Decided by User, as Good as it gets* **Use Case:** *Use whenever single data points are available* **Desirability**: *Highest, shall be default dataset to use*	**Product Family**: Solid Rocket Motors ***MCPLX = 9.4644 × Weight$^{-0.058}$*** *Weight Range: 16.7–80,900 kg* *Data Points in Total: 16* *… within ±20% error: 9* *(data points undisclosed)* **Cost Modeling Accuracy:** *Acceptable* **Use Case:** *Use when data must be shared without disclosing single data points!* **Desirability**: *Medium, shall only apply to controlled exchange of data*	**Product Family**: Solid Rocket Motors **MCPLX = 6.266 (Mean)** *Weight Range: undisclosed* *Data Points in Total: undisclosed* *… within ±20% error: undisclosed* **Cost Modeling Accuracy:** *Anecdotal (cannot be verified)* **Use Case:** *Use when no better alternatives are available* **Desirability**: *Lowest, shall be avoided*