

CHALLENGES ABOUT DECISION MAKING PROCESS AND HUMAN FACTORS IN COMMERCIAL SPACE OPERATIONS

A Pilot's Perspective



Disclaimer:

- *personal opinions reported – not VG's position*
- *Non-ITAR material presented*

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- Only **559 individuals** have flown in space so far since Yuri Gagarin's first flight in **1961!**
- Only **3 Countries** (Russia, U.S.A. and China) and **1 private company** (Scaled Composites) have been able to successfully design, build and launch spacecraft with humans in **56 years...**



- If humankind **has to become** a space fairing civilization, then **thousands, if not millions, will have to fly** in space (suborbital, LEO and deep space)

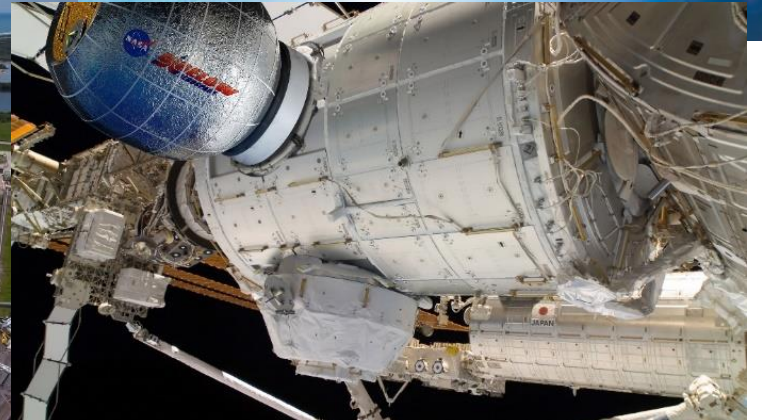
- Similarly to the expansion of commercial aviation in the '30s and post WWII, **we can successfully grow commercial operations, business, wealth and massive permanent presence of humans in space in our lifetime**



- **Government Agencies are not** the way forward to achieve this due to high expensive running costs and/or few launches per year:
 - ROSCOSMOS - *budget uncertain and unstable, continuously delayed programs*
 - NASA - *unclear vision for future human space exploration; planning to fly 1 manned Space Launch System per year in deep space from 2021*
 - Chinese – *good progress but very slow – undefined objectives for future*
 - ESA – *a continent with population 443M and 13 active astronauts....No independent access to space...*

What are the options left?

Many commercial space vehicles under development



Challenges of commercial space operations

- Accessing space is **significantly inherently dangerous – Space is hard!**
- Flying humans to space is **at least two orders of magnitude more difficult** than launching payloads/cargo
- Commercial operators/manufacturers **lack years of experience** Government Agencies have accumulated in 56 years of human space flight
- To stay in the market, **commercial players must be profitable:**
 - Potential reduced manpower to achieve goals
 - Availability of defined budgets
 - Avoidance of program delays
 - **“Pressure to go - launch” to stay profitable – taking shortcuts to safety**

Poor Decision Making process

Poor Mission Risk Assessment

Decision-Making

In psychology, **decision-making** is regarded as **the cognitive process resulting in the selection of a belief or a course of action** among several alternative possibilities. Decision-making is **the process of identifying and choosing alternatives based on the values, preferences and beliefs** of the decision-maker.

Risk Assessment

Risk assessment is the determination of **quantitative** or **qualitative** estimate of risk related to a **well-defined situation** and a **recognized *threat*** (also called *hazard*).

Quantitative risk assessment requires calculations of two components of **risk (*R*)**: **the magnitude of the potential loss (*L*)**, and **the probability (*p(L)*)** that the loss will occur. An **acceptable risk** is a risk that is **understood** and **tolerated**, usually because **the cost or difficulty of implementing** an effective countermeasure for the associated vulnerability exceeds the expectation of loss.

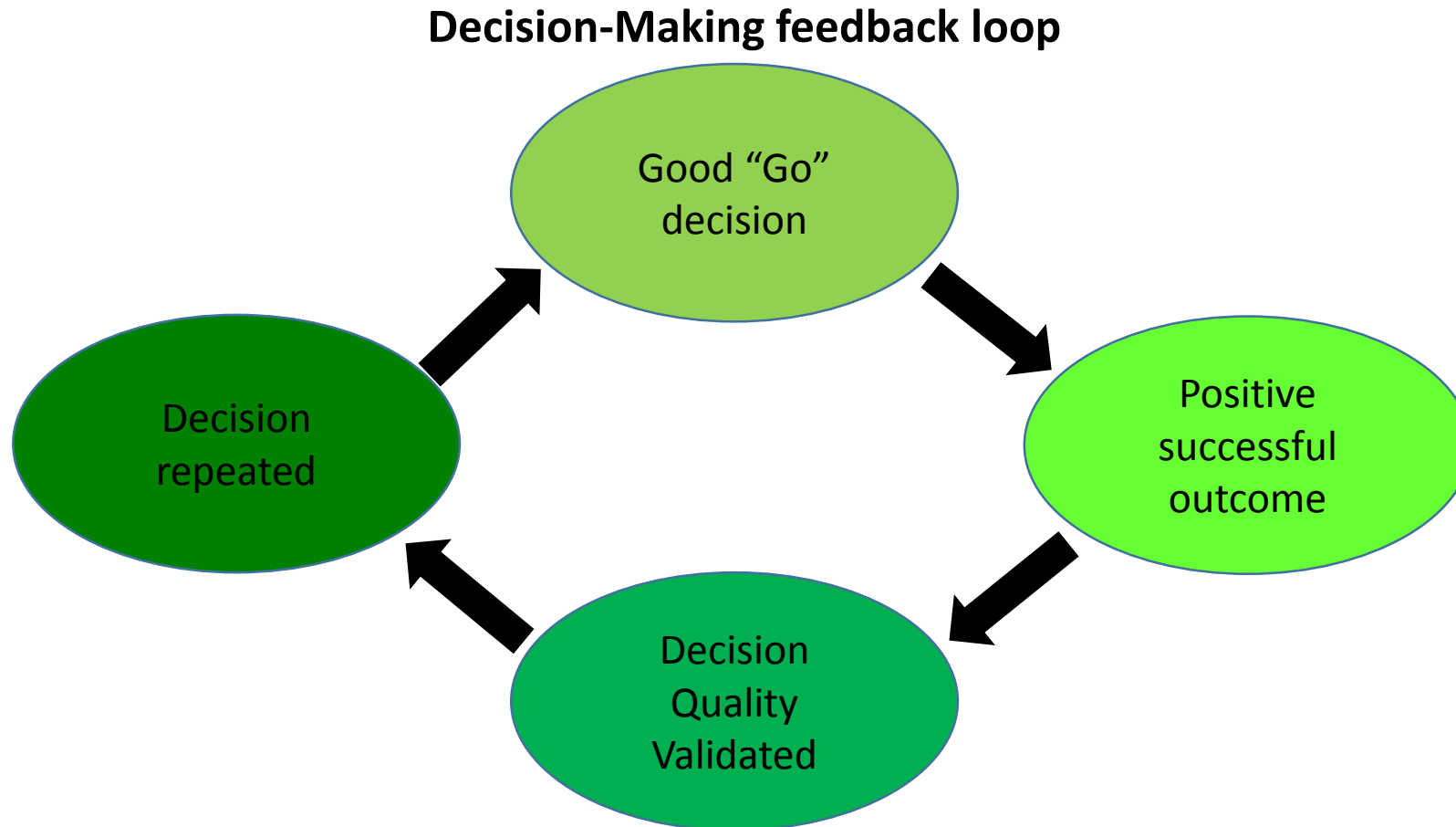
$$R_{Total} = \sum_i L_i p(L_i)$$

L_i = *magnitude of potential individual loss*

p(L_i) = *probability for L_i to occur*

Risk Assessment drives Decision Making

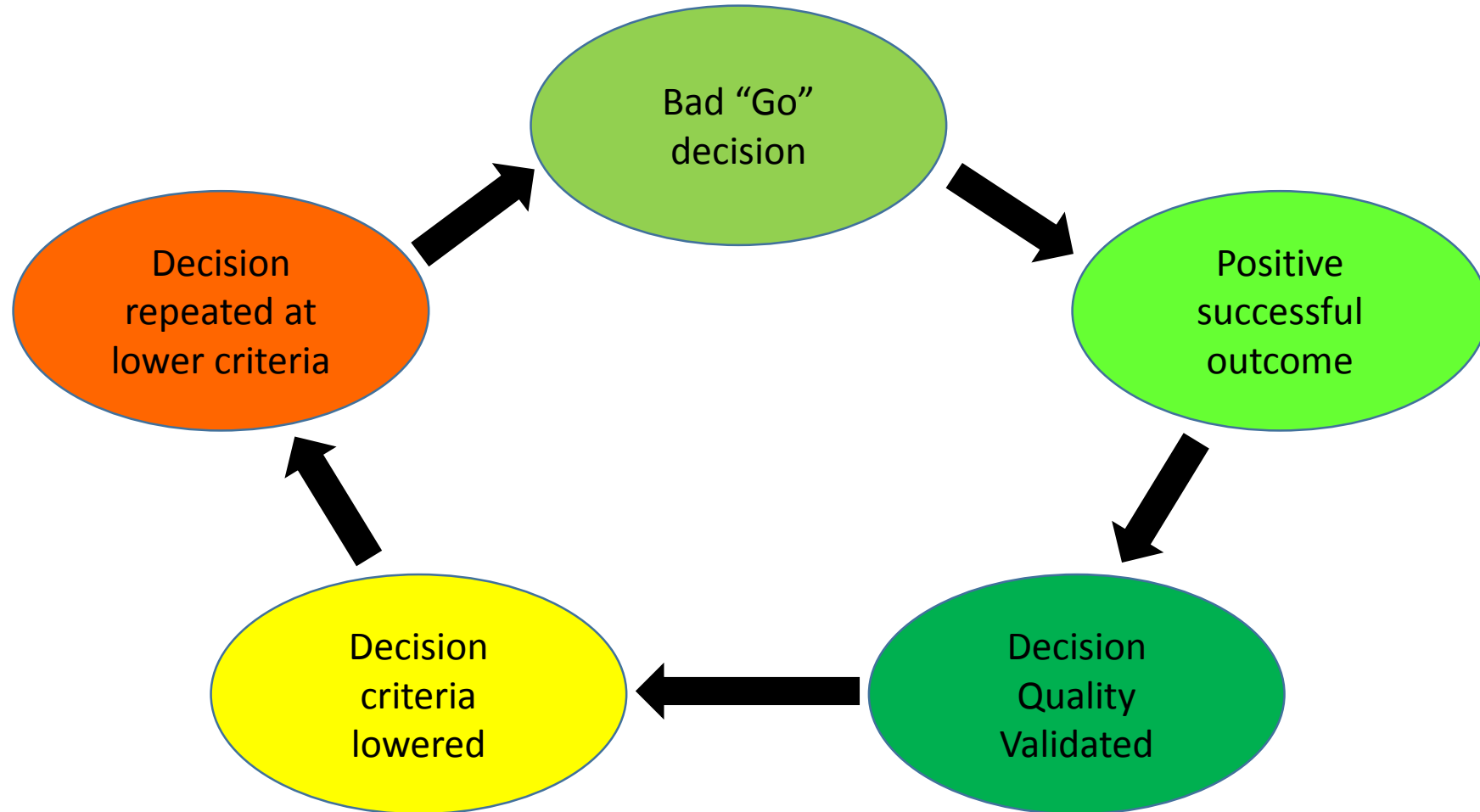
- The “Go” decision **requires a high degree of confidence in a positive outcome**, if negative consequences are catastrophic
- **Bad decisions** are made because **we are reinforced by not seeing bad outcomes** from previous bad decisions



Feedback loop with reduced standards

- Decision Makers can become **victims of human psychology**
- **Quality of decision** drives **safety**

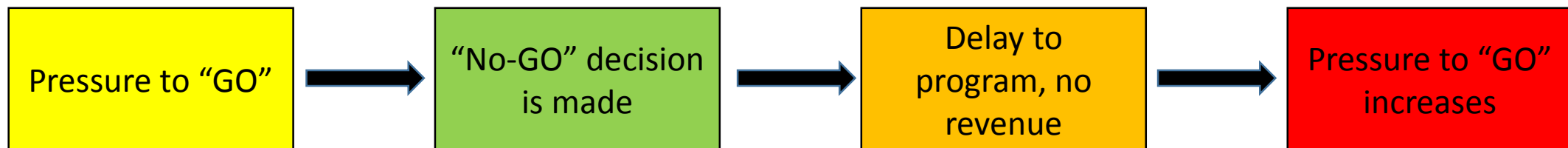
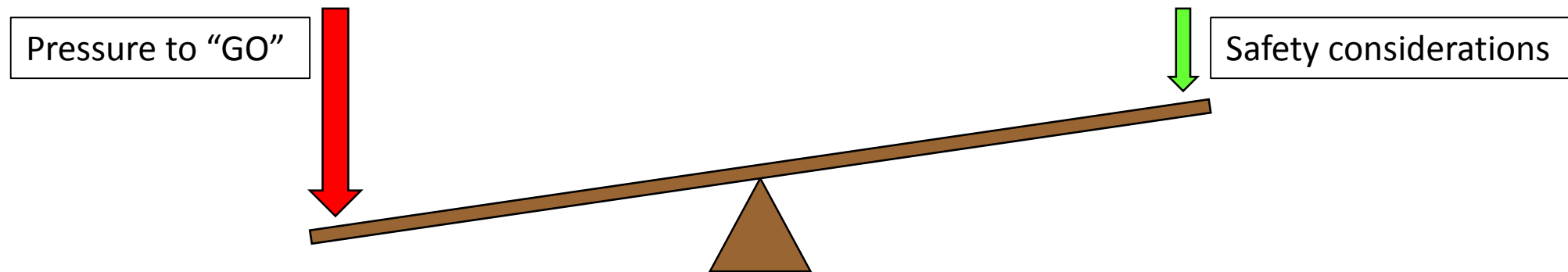
Feedback loop "reduced" with Bad "Go" Decision



Probabilities and human psychology are the enemies!

- Inherently **deceptive mathematics of probability** challenge the human nature
- **We are “prisoners” of self deceptive psychology** involving the quality of our own made decisions and the **inevitable pressure we face** to make the go decision

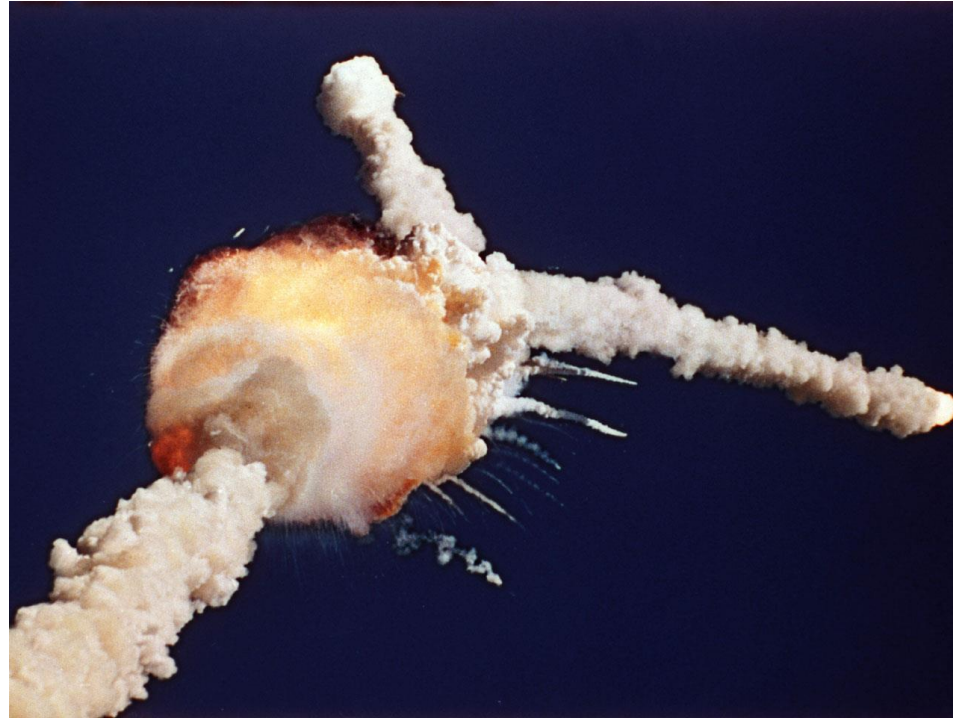
If 99% probability of success \rightarrow For 18 attempts $P = 0.99^{18} = 0.835 \rightarrow$ 83.5 % of success in 18 attempts
(1/6 chance of failure!)



Study cases of the consequences induced by the pressure to “GO”....



Jan. 27 – 1967
Apollo 1 Pad fire



Jan. 28 – 1986
STS-51L Challenger Explosion on ascent



Feb. 3 – 2003
STS-107 Columbia re-entry accident

Has the aerospace community learned from these lessons?

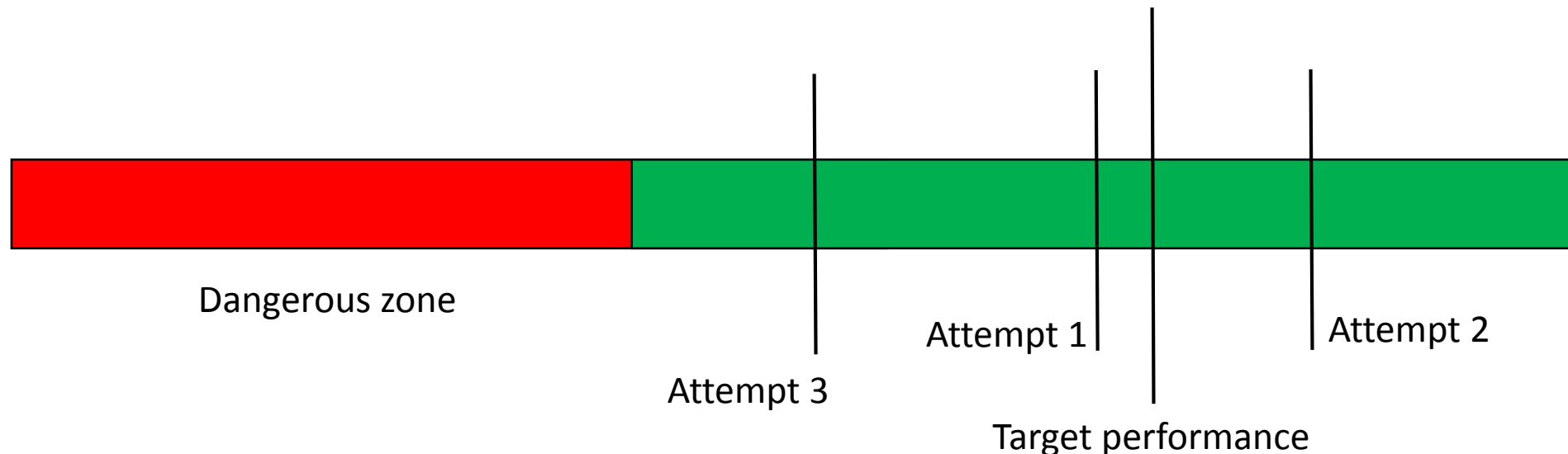
October 31, 2014 – SpaceShipTwo VSS Enterprise accident

Another example of underestimating the power of bad decisions and the revalidation of bad decisions...



What are the solutions and mitigating actions available?

- Unfortunately, **no easy answer** to the problem
- **Two strategies are possible:**
 - continuous awareness of the pressure for the “GO” decision
 - expand the scope of lessons learned; disseminate information (symposia, conferences, etc.)
- **Quantitative analyses** of the decision-making process: **are we lucky or good?**
- Decision to “GO” and statistical adversities **will be balanced by actual data** and **conscious risk mitigations**



Actions taken on SpaceShipTwo program

Organization aspects

- **Merging of Virgin Galactic's operations with The SpaceShip Company engineering**
 - One Program Manager, one CEO
- **Thorough process of risk mitigation and unanimous consent on important decisions**
- **Grow and nourish a “culture of reporting” at all levels** – Anybody can inform management of an issue at any time, even if pressure to “GO” is rising
- **Independent safety team tracking technical and programmatic risks**
- **Independent external review team assessing Company's “Pressure to GO”**
- **Direct involvement of FAA in all aspects:**
 - Engineering modifications
 - Flight Test Licensing and Commercial Operations aspects
 - Witnessing of simulator sessions and flights
- **Assistance of two highly experienced flight surgeons:**
 - Monitoring pilot's physical and mental conditions
 - Involved in training and medical assessment of SFPs



Actions taken on SpaceShipTwo program

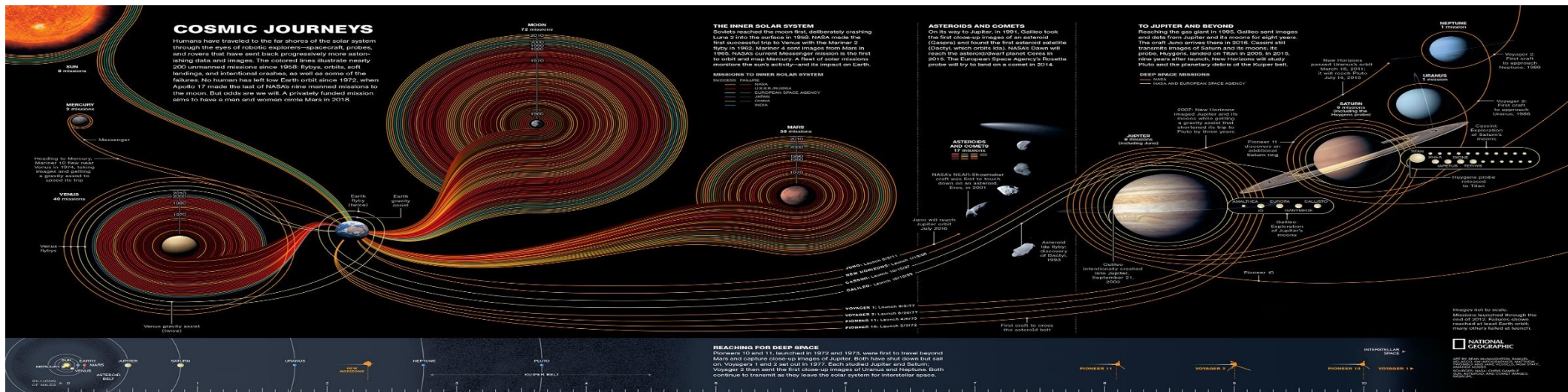
Technical aspects

- **Hiring of 7 “seasoned” experimental test pilots:**
(although not invincible...)
 - average 25-years of test experience, average of 8000 hours flown on hundred of aircraft
 - all former military test pilots, extensive experience on a unique variety of different vehicles
 - extensive experience in civilian/military aerospace industry and agencies
- **Integrated simulator sessions with all MCC room and flight crew**
 - Detailed attention to CRM aspects and cockpit workload in the crew and with MCC
 - Intense modification of cockpit to improve human factors
- **Resolution of any technical single point failure on VSS Unity**
- **Addressing of bad design choices from original design and implementation of technical solutions**



Final Considerations

- Although Space is Hard, humankind has the technology level, skills and knowledge to truly become a space fairing civilization
- The answer might be in commercial space companies, however many challenges need to be addressed and solved for these “newcomers”
- Decision-making process will have to consider the laws of probabilities and the human psychology to press on when risk is not well understood
- Humans remain the weak link in any human factor consideration of a piloted and unpiloted vehicle
 - The top challenge in future space exploration lies in the human mind
 - Permanent presence of millions of humans in space or other planets is only possible if aerospace medicine will learn how well to characterize psychological challenges and cope with them



*“The Earth is the cradle of humanity,
but one cannot live in the cradle
forever.”*

Konstantin Tsiolkovsky, 1911



Questions ?