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

A Pilot’s Perspective

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Disclaimer:
- personal opinions reported – not VG’s position
- Non-ITAR material presented
• 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 faring 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 humanpower 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.

\[
R_{Total} = \sum_i L_i p(L_i)
\]

$L_i = \text{magnitude of potential individual loss}$

$p(L_i) = \text{probability for } L_i \text{ to occur}$
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.

Decision-Making feedback loop:
- Good “Go” decision
- Positive successful outcome
- Decision Quality Validated
- Decision repeated
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

1. Positive successful outcome
2. Decision criteria lowered
3. Decision repeated at lower criteria
4. Bad “Go” decision
5. Decision Quality Validated
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 ➞ For 18 attempts $P = 0.99^{18} = 0.835$ ➞ 83.5% of success in 18 attempts (1/6 chance of failure!)

Pressure to “GO” ➞ “No-GO” decision is made ➞ Delay to program, no revenue ➞ Pressure to “GO” increases

Safety considerations
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