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A Hierarchal Decision Model to Determine the Most Promising Tier-2 Space Agency

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ABSTRACT

When it comes to space exploration programs NASA, ISRO, SpaceX, CNSA, JAXA and ESA has made remarkable achievements in the past and is keep making more and more success. The study, on completion, seeks to guide the decision problem of "which space agency has the best future in space exploration?".

This study will seek to find which space agency has the best future prospect in terms of various perspectives. To find a solution to the stated problem, initially available literature was studied and the probable solutions for the decision problem was enlisted. Data Records from the organization websites were studied to determine financial, impact, technical, track record etc., which was followed by a hierarchical decision model (HDM) by mapping out the different factors that affect the preference of country with orbiting space program. A panel of 6 experts was chosen and were requested for assistance to evaluate the model and then the results were evaluated and compared. After further analysis, additional decision-making changes may be done. Revisiting the opinion of panel of experts may or may not conducted to draw the conclusion in the entire decision-making process.

The biggest drawback of this study is that the data used for quantitative analysis by the panel of experts. The panel doesn't include individuals from every organization of the alternatives, resulting is lack of confidential information of these agencies. For future research, study based on data sources from every alternative organization would be helpful as that would affect expert preference and opinion.

Keywords: space exploration, space agency, future in space, tier-2 space agency.

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1. INTRODUCTION

Ever since antiquity human civilization had dreamed of exploring space, It seemed impossible for a long time until Sir Isaac Newton showed us how gravity works, That gave us ideas of how to escape it and we transformed theory to reality. Not too long ago; on October 4th, 1957 the soviets launched their first artificial satellite, Sputnik 1. Four years later, on April 12th, 1961 the first human orbited the earth in Vostok 1(A Brief History of Space Exploration). Just in these few decades we have come a long way from there, we have sent two voyagers to explore outer space, sent men to the moon and today about 1100 satellites orbit the earth (Ritter, 2014). Today, in the year 2018, we are even taking about sending our men to our neighbor, Mars too look for prospects of human colonization in Mars. So far NASA and ROSCOSMOS has lead us in multiple manned and unmanned space projects. With their assistance and leadership, a lot of other space agencies has emerged over the years. Some have successfully launched multiple mission, other are known for their incredible Research, Development and Innovation. But among them who will be the next to lead us in further space exploration?

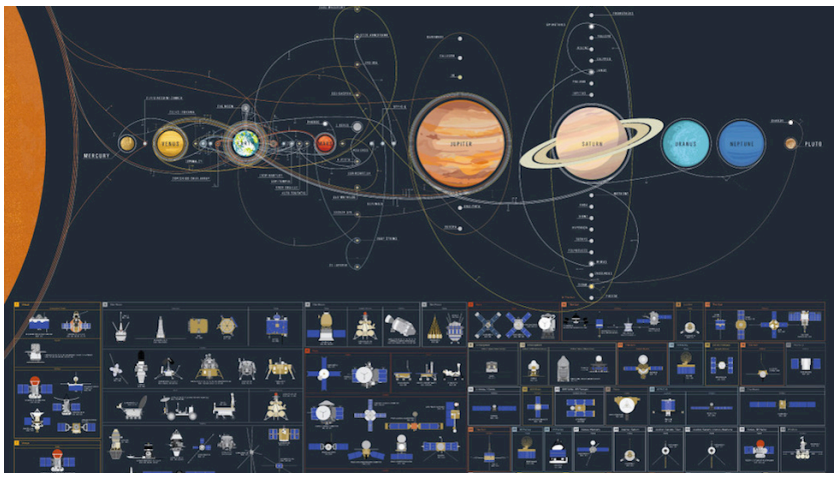


Figure 1: A brief history of Space Exploration

In the history of space exploration NASA and ROSCOSMOS's contribution is undeniable. In their space race to eliminate each other's lead they introduced us to the Space Age (McDougall, 1997). The beginning of the Space Age gave emergence to multiple space agencies and blessed us with numerous achievement

and is keep giving us more. ESA made a soft landing on a comet using Rosetta (Glassmeier, 2007), JAXA collaborated with NASA to grow lettuce in space (Herridge, 2015).

But in the recent years of this Space Age other agencies are creating revolutionary changes in the technology and development of space exploration. SpaceX is showing us the reusability of rocket parts, ISRO is showing us how money is always not the key factor in space exploration and CNSA has successfully explored moon more than once and has their own space station. It is time to evaluate who is going to be the most successful and lead us in the future.

2. THE METHODOLOGY OVERVIEW

This section gives a stepwise overview of the methodology of the project. (Henry, 2018) Information on how each step was approached and executed is given under each of the sections. The decision model methodology comprised of the following steps:

1. **Definition of the decision Problem:**

   The decision problem was selected, followed by significant research, literature review and choice of experts. The decision was made by approaching the decision problem from perspectives that affect the development of space agencies that is discussed further in the study.

2. **Selection of the decision methodology**

   The Decision-Making Model selected for the decision process was Hierarchy Decision Model (HDM), a refined version of Analytic Hierarchy Process (AHP), HDM was chosen due to availability of tool, knowledge and choice of topic.

3. **Selection of the initial model**

Based on the initial research and literature review an initial model as designed. Literature review was followed by choice of perspective and criteria. The model was then validated.

4. **Validation of the model**

   The Initial model was checked with the small portion of the subject-matter experts panel. Upon discussion with the experts, alternatives were determined, few changes in the model were made. And a final model was designed.

5. **Design of the final model**

   Considering the feedback of the experts a newer model was designed. Alternatives were reduced, perspectives were changed and a part of the criteria were replaced with new ones.

6. **Collection of data from experts**

   The from the experts were collected using the HDM tool developed by Portland State University.

7. **Processing of data, conclusions and recommendations**
8. **Suggestion of future research**

Definition of the Decision Problem

It is well described in the introduction that the decision problem is "Which space agency has the most promising future?" Initially the decision problem was completely different with a different set of alternatives. The problem alternatives that were considered during the initial steps of the project were:

- What is the best new mode of transport suitable for Trimet to connect the southern part (Clackamas Town Center, Beaverton TC and Wilsonville) of the Portland Metropolitan?
- Which country is leading in Space Orbiting Program?

The first decision problem was rejected due to absence of relevant literature. Initial steps were made to consult experts but the relevant required quantitative data collection was time consuming and partially confidential and would more likely be successful as a deeper research question.

The second alternative question was approached and discussed with the instructor. Upon discussion it was concluded that the solution to the decision problem was evident and as a study it would not be significant or necessary. The recent development in Space exploration was taken into account and with consultation of the instructor the question was modified to "Which Agency has the most promising future?".

The modified decision question was finalized and was moved forward with.

Selection of the decision methodology

Advantages, &Disadvantages of HDM and ANP were considered before selection of the decision method. Based on availability of sources and the decision problem the methodology chosen was Hierarchy Decision Model (HDM). Hierarchy Decision Model is a refined adaptation of Satty's Analytic Hierarchy Process(AHP). HDM was developed by Cleland and Kocaoglu (Cleland, 1981). AHP in general considered advantageous for making decisions based on human input. The problem in AHP is broken in multiple smaller criteria and sub-criteria, thus giving a deeper insight on what affects the decision problem and what doesn't.

One of the few disadvantages of AHP is the potential of information loss due to aggregation of scores that may cancel each other out on the same level of the hierarchy (Henry, 2018). The HDM model was selected because of its ability to break down a complex problem. The availability of the web-based tool of Portland State University's from the Department of Engineering and Technology Management was and hands on and helped with collection of data from the subject-matter experts and calculate the necessary calculations.

Selection of the Initial Model

After reviewing literature in the relevant subject an initial model was plotted with Perspectives and Criteria's as shown in the diagram.

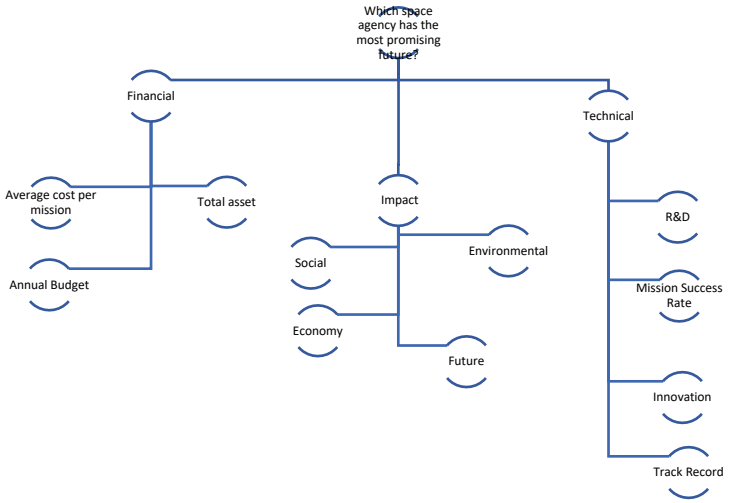


Figure 2: Initial HDM

With Alternatives that included:

NASA ROSCOSMOS ESA JAXA ISRO SPACEX MARSONE CNSA

The experts were approached with the model and validation was asked for.

Validation of the Model

The validation expert panel included:

a. Space Instrumentation Research Scholar ISRO

b. Member of NASA Educators Online (Process Control Engineer & Professor)

Upon approaching the experts studied the model and discussed the necessary changes that was to be considered.

Design of the Final Model

With discussion, consultation and validation of experts a final model was built taking all the opinions of the experts into account. The model was built on the PSU HDM web-based tool and the final model looked like the following image.

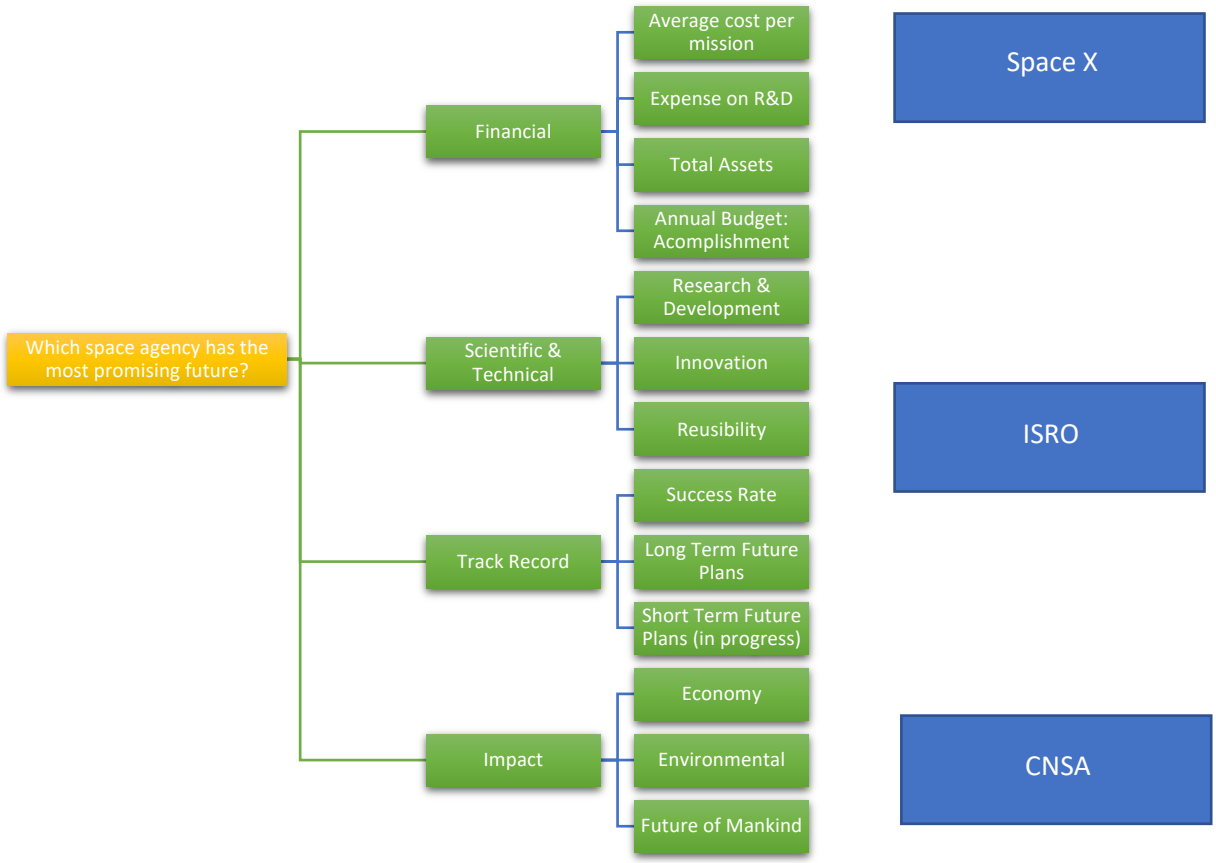


Figure 3: Final HDM

3. THE HIERARCHICAL DECISION MODEL TREE

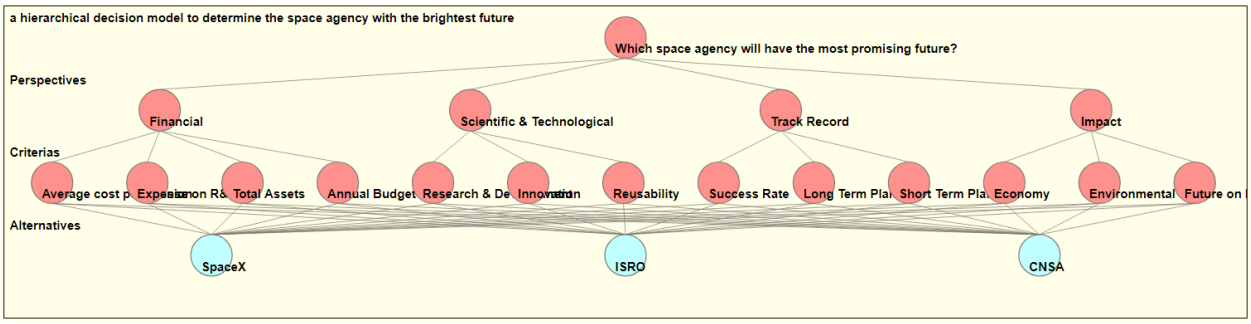


Figure 4: The HDM in the PSU we-based tool

The Hierarchical Decision Model Tree that was created four levels. The levels were:

- The Decision Question
- The Perspectives
- The Criteria
- The Alternatives

The Decision Question:

This is the first level of the decision-making tree of the HDM Model. The Decision Question states "Which space agency has he most promising future?". The question itself was built based on selecting the best "Tire2" space agency. Initially the decision question was "Which Country has the best space orbiting program?". Later, after consultation with expert and instructor the question was changed. The decision question was looked at from four different perspective which were further explored down the decision tree. The four different perspectives that were discussed are seen below.

The Perspectives

The second level of the decision-making tree of the HDM Model. They were concluded after consulting literature. It represents the different perspective from which the decision problem is looked at. They are:

- Financial
- Scientific & Technical
- Track Record
- Impact

Financial:

This section explores the financial requirements, expenses and values of each of the alternatives. This section is further divided into four criteria that are significant to the growth and existence of a space agency which are explored in a third level of the decision tree.

Scientific & Technical:

Probably the biggest and most important perspective of the lot. This explores the scientific development, research, innovation, technical achievements. The perspective will further look down to individual achievements of each agency and their innovations in the field. This perspective has been looked from three different criteria in its next level.

Track Record:

A very important aspect of the space agency industry. This perspective not only shows the capability and strength of an agency but also shows its plans and ambitions. The track record of a space agency, even if its short, can show its place among others. This section was furthered explore into three other criteria in the next level of the decision tree.

Impact:

Space Age has brought us fresh facts about our home planet and out neighbors. With every space mission we execute we harm and risk our own lives and planet a little more. Along with that the development of our civilization and continuous increase in our population, fictional concepts like colonizing outer space or changing industrial regions to outer space have been brought up and multiple space agencies are working on such concepts. In this aspect every step a space agency takes impacts us every day in a variety of way. This perspective is further divided and explored into three major criteria in the next level of the decision tree.

The Criteria

This represents the third level of the HDM tree. Each criteria is a sub section of a particular perspective. The 13 criteria that have been listed to affect and add weight to the existence of a space agency are listed underneath their specific perspectives as follows

- Financial
  - Average cost per mission
  - Expense on R&D
  - Total Assets
  - Annual Budget
- Scientific & Technical
  - Research and Development
  - Innovation
  - Reusability
- Track Record
  - Success Rate
  - Long Term Plans
  - Short Term Plans
- Impact
  - Economy
  - Environmental
  - Future of Mankind

Financials:

Average cost per mission:

The cost of a space mission can vary from launch to launch. The cost could depend on the mission which can range from a space shuttle to the International Space station to a rover to the moon. The average cost to launch a space shuttle is $450 million according to NASA. But depending on the team, the financial strength of the company and the technology the cost vary of similar missions. This criterion of a space agency looks at the financials from the average cost and efficiency point of view.

Expense on R&D:

The development and success of a space agency depends on what they do different from other agencies. And that depends on how much amount of money a company invests in the research and development. Companies like SpaceX and ISRO not only have their own money invested in R&D but also has other collaborations with NASA and JAXA who have invested a great deal for research and development.

Total Assets:

Assets, like in any other company, is a major factor which determines the financial strength of the company. More assets for space agency means the richer it is and the better it's capabilities are to carry out successful mission. NASA is a near ideal example from that point of view. For example, CNSA owns not only several research centers but also a space station, Tiangong-2, as an extension of their research center. In terms of space age assets, a space station is very significant and valuable.

Annual Budget:

Above all financials in a space agency the annual budget matters the most as the annual budget gives company the power to invest in R&D or acquire and build assets. Privately owned companies like SpaceX and Blue Origins are fortunate in this respect as they get funded from renowned organizations and venture capitalists along with their funds spend on them by their billionaire owners. Most of the times having a a higher annual budget gives a company an upper hand on productivity and success.

Scientific & Technological:

Research and Development:

Not to be confused with the financial expense on Research and Development. This aspect of a space agency refers to the research and development of a space agency that leads to the innovation and development of new technology. Most Space Agencies in the world without any launches rely on their research and development which leads to gathering of knowledge. Without research and development, we would not have Teflon based frying pans.

Innovation

Innovation is one of the core aspects of science and technology irrespective of the field. Innovations makes you different from everyone else and space agencies have been proving themselves by innovating new concepts every day. From reusability of shuttles to usage of eco-friendly fuel or having super cheap yet efficient space mission models have been few of the recent innovations that have made the headlines.

Reusability

We live in a world were sustainability, value creation and knowledge run side by side. In contrary to age old beliefs that sustainability cannot run along with creation, companies like SpaceX has made reusability of parts space shuttles possible (Vozoff, 2008). The concept became a trend and is one of the most important features of space agencies. Followed by SpaceX, NASA, ESA, ISRO, CNSA and multiple others have adopted this sustainable concept to decrease pollution and space debris.

Track Record:

Success Rate:

The best way to judge the efficiency, achievement and accomplishment of a space agency is to look at what they have done in the past, how successful were they and how far are they willing to go to outshine others. Success rate is one of those parameters to judge a space agency. The biggest and most successful space agency like NASA had a success rate of around 85% in the mid-20th century (Kyle, 2017). Whereas ISRO an organization that was born not too long ago has only 2 failures in its history. This parameter will judge the alternatives according to their success rate.

Long Term Plans:

Long Terms as a criterion looks forward to exploring the long-term ambitions and goals of a space agency. NASA has been a model for long term goals for a lot of companies with its Voyagers. Launched more than 40 years ago, NASA had long term plans to gather information about the interstellar space. Till today we receive information and regular updates on its movement as they head towards different stars. Agencies like Blue Origins and SpaceX have long term goals to make humans a multi-astronomical object species. Colonizing Mars and the moon has been the talk of the town for a while and agencies are working hard to make it happen (Fouing, 2016)

Short Term Plans:

Short Term Plans is another criterion, pretty close to long term plans that show the what the space agency has in store in the near future. NASA, ROSCOSMOS and SpaceX has a pretty strong layout of both short and long term whereas Tier 2 agencies like ISRO, CNSA and JAXA reveal their short-term plans slowly. A lot of the time have low financial power lead to no long-term plans and few short-term plans. Even with agencies who has lower financial allocations in infrastructure like ISRO seem to have very strong short-term plans (Murthi, 2009).

Impact:

Economy:

In the space age the existence and capability of a space agency impacts the economy of the country by a lot. From an economic point of view, execution and success not only gives a head start in the scientific development of the country but also economic head start. Success, research, development all tie together and bring in investors and helps in the economic development of the company.

Environmental

Like mentioned in the “Reusability”, sustainability has become a big part of our society and one of the biggest things that we must sustain is environment. This criterion looks at the space agencies and the measures they are taking to sustain the environment and controlling its impact on the environment. For example, ISRO has recently developed a green fuel for launching rockets and trying to replace hydrazine fuel source.

Future of Mankind

"Is there life on Mars?" – A line from a chorus of the famous song by singer David Bowie asks a question that we have already been asking for decades. Looking for life and habitable conditions has been one of the primary goals of space research. Scholarly articles have been written and researched over the decades (Zubrin) (Schenker, 2003). Economic and scientific feasibility have been analyzed and companies like SpaceX (Musk, 2017) and Mars One (Do, 2014) have promised to send humans to mars with the objective to make humans colonize. Blue Origins wants to take human settlers and make industrial zones in the moon. Space research is in a position where human civilization would go downhill form here or spread across the universe. This is a very important criterion that impacts human civilization highly on their long-term plans.

The Alternatives

Determining the alternatives, the was one of the most difficult points faced during writing this paper. While researching no distinct research on emerging or Tier 2 space agencies were found. Most of the research on space that were popular were NASA based or by a wing of NASA. The initial alternatives included NASA, ROSCOSMOS, JAXA, ESA, ISRO, CNSA, SpaceX and Blue Origins. After consulting experts NASA, ROSCOSMOS and ESA were rejected from the list as these organizations are too big and are most likely to take the lead anyway. JAXA and Blue Origins were comparatively brand new. Even though JAXA is new it has a great track record and is way ahead in certain fields. It is a successor to three huge space research agencies from Japan that adds to it credibility. So, its achievements and financial strength would give the lead anyway (22). Blue Origins has been relevant in the news recently with their new long-term plans of settling humans in the moon. But in terms of achievements it has mostly done testing and small contract research and development for other organizations. Even though it is owned by the richest man in the world

(Calfas, 2018), the organization doesn't have financial strength even close to organizations like SpaceX, ISRO, CNSA. So, the final Alternatives that were chosen as alternatives were:

- SpaceX
- Indian Space Research Organization
- China National Space Administration

SpaceX:

SpaceX, a company founded very recently, in the year 2002, has made quite a difference in the space industry (SpaceX). With its futuristic concepts, constant efforts, research, and innovation this organization have certainly made its mark in the history of Space Age. It is the first privately owned company whose launched rockets have returned from the low-earth orbit. SpaceX has not only has completely taken over taking cargo to the international space station but also has helped multiple countries all around the world launch rockets. SpaceX ambitiously jumped into the aerospace industry and launched 18 successfully rockets in the year 2017. And as of today, in the year 2018, SpaceX has launched its 11th rocket within the first four months of the year. With their revolutionary innovation and the Falcon rockets, SpaceX is conquering the aerospace industry. They have changed the game with their affordable engines, and material usage reduction along with cost (Seedhouse, 2013). And with time they are innovating better technology to make rocket launches even cheaper (Bjelde, 2008). SpaceX is so relevant in the industry that almost every day it makes some form of news. According to the director of SpaceX, Motley Fool, SpaceX has a revenue of $1.3 billion and makes a profit of $195 million (infrographics.com). As of 2018, SpaceX has a value of $28 billion and has "unlimited funding" (Sheetz, 2018). SpaceX has even dared to promise the world to make civilization possible on Mars (Musk, 2017). With their long-

term oriented business model, incredible success rate, cheap rocket launching rates, and investors, this agency is not slowing down or going downhill anytime soon.

ISRO:

Founded in 1993, Indian Space Research Organization (ISRO) has made its mark in the space race by achieving several launches in very little time. It didn't take long for India to go through the first two stages of development- acquiring initial infrastructure and launch testing systems (Mahanty). India's concentration has been on civilian application related to social and economic development (Sadeh, 2013). Along with-it India has also been actively participating in launching satellites, collaborating with several bigger space organization. Other than China and Japan. India seems to have a significant hold in the Asian Space war (McDougall, 1997). With its collaboration with NASA in NISAR, Mangalyaan - Mars mission it is one of the few space agencies that have a brilliant track record. ISRO also seems like it has been significantly affect he economy of India by commercializing technologies through their research and development. With its sister organization "Antrix corporation" ISRO has been developing technology, weapon and space probes and commercially selling them in global markets (Mahanty). With an annual budget of approximately $1.7 billion, ISRO is at the peak of its history and it doesn't seem to turn back with it it's future (ISRO)(Department of Space,Govt. of India). ISRO has also impressed the world with its Mars mission named "Mangalyaan" and several satellites with cost that is significantly lower than other renowned agencies like NASA (Sundararanjan, 2013).

CNSA:

Out of all the alternatives, to gather information from CNSA has been the most difficult. From the little information gathered, China at outer space as an asset. Founded in 1993, this national

organization has made international alliances with Russia and Pakistan and has made impressive leaps of success so much so that it is said that China is in a space race with the United States and India (Seedhouse, 2010) (Moltz, 2011). Every step NASA takes, CNSA has tried to compete and outshine itself. Most of CNSA's data are confidential except for the few archived web pages. According to those pages China has an annual budget of $1.3 billion (Brown, 2009). Looking at China's achievement, economy and missions the information might not be correct. According to Joseph Santino (name changed), who has worked under a Chinese business model says that confidentiality of critical information is not uncommon in companies. China has a brilliant track record in its lunar missions. As long-term missions CNSA does want to have manned bases in the moon to further expand its horizons in exploring outer space (Yonchun, 2008). Other than the International Space Station the only other space station which is active is controlled by China which gives them a lead in assets, technology and research (China Power Team).

4. THE PANEL OF EXPERTS

The panel of experts that were consulted were as follows:

Sl. No.	Expert	Designation
1	Expert 1	Space Instrumentation Research Scholar – ISRO, INDIA
2	Expert 2	SpaceX enthusiast, electronics engineer, USA
3	Expert 3	Student, Computer science engineer, USA
4	Expert 4	Process control Engineer, Professor- NASA Educators online, INDIA
5	Expert 5	MBA, Business Model Analyst, INDIA
6	Expert 6	Student, Instrumentation Engineer, INDIA

Expert 1 and Expert 4 were the primary help sources to layout the HDM model. Both being experienced in space sciences and the exploration of history helped correct the initial mistakes of the model. Expert 2, who has done several curricular projects on SpaceX and NASA and is a space science enthusiast brought up an excellent criterion that could have been added. According to Expert 2 "Safety" could have been added as a criterion under the perspective "science & technology". The opinion could not be taken into consideration as most of the data were already collected. Even though the success rate points towards "safety" of a mission, it would have been a good addition to the model and could lead to different outcomes. Expert 5, MBA and Business Model Analyst, who is also and electronics and communication engineer, guided and briefly discussed the financial side of the project and help construct the financial sub criteria and what could matter to an organization. PSU's PSAS (Portland Space Aerospace) were contacted as well, but after initial contact, it was difficult to get back from the PSAS experts.

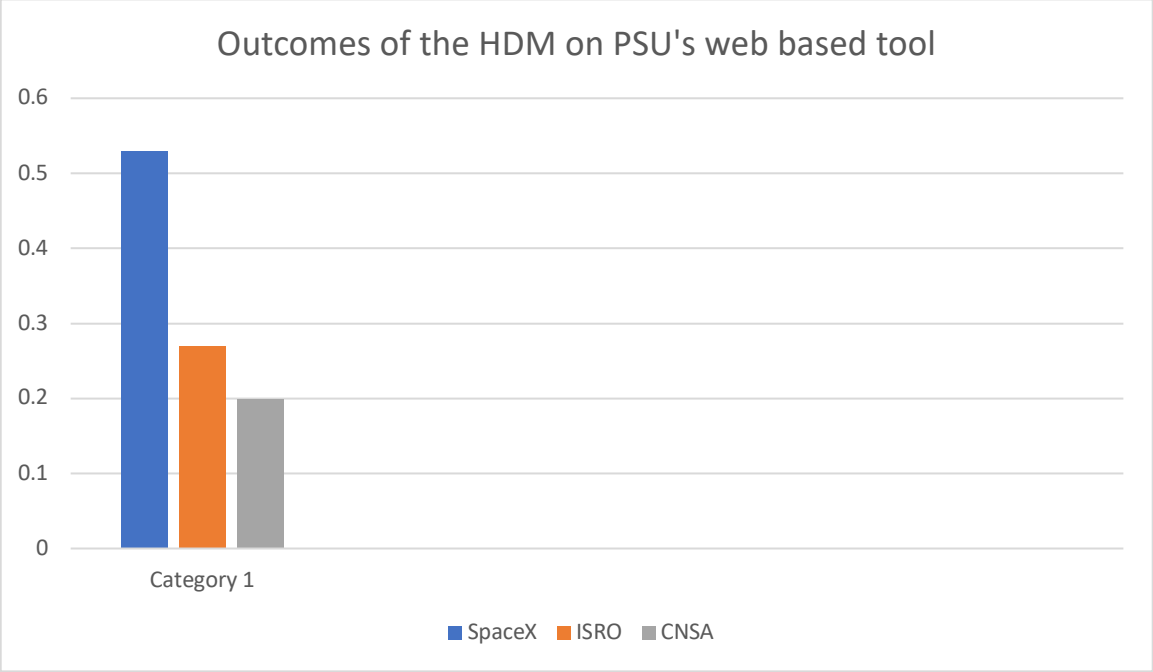
5. THE OUTCOMES AND THOUGHTS

Keeping track record, finances and ambitions in mind the probable winner of this decision-making model was thought to be CNSA. CNSA has the most assets, their own space station and China's space science roots are much older than ISRO or SpaceX. CNSA has more diverse range of projects and missions and clearly was assumed to be the front runner. With literature saying that China was strong enough to compete US in the space race, backed up the idea of CNSA to have the most promising future. But surprisingly the results were completely different. The results looked like the following figure:

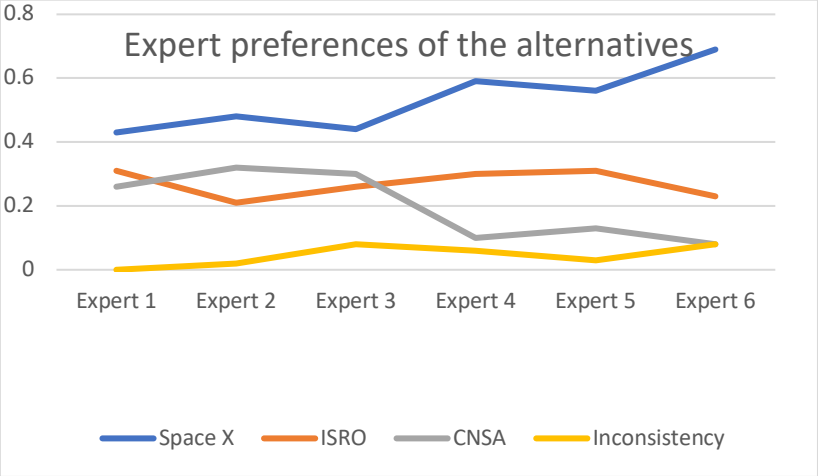
Which space agency will have the most promising future?	SpaceX	ISRO	CNSA	Inconsistency
Expert 1	.48	.31	.26	0

Expert 2	.43	.21	.32	.06
Expert 3	.44	.26	.3	.08
Expert 4	.59	.3	.1	.06
Expert 5	.56	.31	.13	.03
Expert 6	.69	.23	.08	.08
Mean	.53	.27	.2	
Disagreement				.078

SpaceX wins. According to the data collected from the experts SpaceX has almost half of the preferences.



Expert 1, who was skeptical and did not provide much information to ensure confidentiality of ISRO's projects, finances and research weighted most of the first two layers of the HDM model equally. Even then, Expert 1's outcome ended up preferring SpaceX. The decision outcome seems to be unanimous. All the experts prefer SpaceX's promises and future. As a result, the inconsistency is a straight line, which is was not expected. The only notable changes that have been observed is the positions of the ISRO and CNSA alternating in the second position followed by SpaceX. This could be a possible bias due to nationality and most experts from India have shown a preference of ISRO over CNSA.



The mean of Level 1 preference is in the following chart:

Level 1	Which space agency will have the most promising future?
Financial	.198
Scientific & Technical	.36
Track Record	.226
Impact	.221

From the observations it can be said that experts prefer the scientific and technical perspective more than any other, which can be understandable as the science and technological development of a space agency leads it forward and ties in all the other factors. It is surprising that Financial

perspective on an average is getting the lowest rating as finances are every important in a space agency to carry out missions. Track record and Impact seem to have more or less the same weightage on an average by experts.

Analysis of Level 2:

Level 2	Financial	Scientific & Technological	Track Record	Impact
Average cost per mission	0.287			
Expense on R&D	0.32			
Total Assets	0.2			
Annual Budget	0.19			
Research & Development		0.19		
Innovation		0.42		
Reusability		0.388		
Success rate			0.43	
Long term Plans			0.2	
Short Term Plans			0.37	
Economy				0.22
Environmental				0.45
Future of Mankind				0.33

This level values show that experts show more concern about the environmental and judge space agencies by their success rate. Innovation, under scientific and technological, which the strongest in an upper level, seems to carry the most weight, followed by reusability. In the finances the

experts look for investment in R&D. Even though most space agencies are long term goal oriented, experts seem to have prioritized Short-Term Plans over them.

Level 3 analysis:

Level3	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
SpaceX	.2	.47	.31	.67	.47	.61	.68	.31	.84	.44	.69	.50	.76
ISRO	.54	.27	.17	.19	.2	.22	.22	.51	.08	.26	.14	.33	.13
CNSA	.23	.27	.51	.19	.32	.16	.1	.12	.13	.25	.22	.13	.12

The chart shows the mean values of the expert opinions. C1 through c13 represent the criteria of level 3 of the HDM model. In C1, i.e., Average cost per mission, ISRO seem to have the lead which makes sense as ISRO is known to make low-cost high-quality spacecrafts. ISRO also seens to be well ahead of its competitors in success rate as statistically ISRO does have a success rate of 95%. CNSA has taken the lead in "Total Assets" which explains CNSA owning more space probes than ISRO and SpaceX and two space stations (one inactive). Pretty much everything else has got SpaceX as the leader.

So to answer the research question directly: *According to this research, SpaceX most likely has the brightest and most promising future among the Tire-2 space agencies.*

6. CONCLUSION

Even though SpaceX is ambitious, it's technology is not quite close to ISRO or CNSA. But it's ambitions are higher and it looks at long-term development of mankind and it has investments and

support of billionaires. In the effort to make science fiction real SpaceX seems like have tapped the hearts of the common people that give it an upper hand. SpaceX keeps itself relevant and popular every day on the news by achieving new goals. Being the talk of the town is probably what made SpaceX get most points in this decision-making research. Followed by SpaceX is ISRO which might have been positioned 2nd by the biasness of the experts from India which makes it one of the drawbacks of the study. Even though CNSA's achievements are high biasness has most likely significantly affected it weights.

7. LIMITATIONS

The main limitations of this study are vast. Firstly, there is a huge lack of concentrated literature on the future of space agencies. Secondly, data on CNSA from verified sources are rare. On top of that the panel of experts selected could have been biased because of nationality and experts closely associated with ISRO may have ignored certain questions to protect confidentiality. I wider panel of experts with deeper understanding and no limitations from all three alternative organizations could have probably given a fairer set of results. For future research it is suggested to rectify all these limitations for a fairer set of results.

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9. APPENDIX

Which space agency will have the most promising future?	SpaceX	ISRO	CNSA	Inconsistency
[redacted]	0.43	0.31	0.26	0
[redacted]	0.48	0.21	0.32	0.02
[redacted]	0.44	0.26	0.3	0.08
[redacted]	0.59	0.3	0.1	0.06
[redacted]	0.56	0.31	0.13	0.03
[redacted]	0.69	0.23	0.08	0.08
Mean	**0.53**	**0.27**	**0.2**	
Minimum	**0.43**	**0.21**	**0.08**	
Maximum	**0.69**	**0.31**	**0.32**	
Std. Deviation	**0.09**	**0.04**	**0.1**	
Disagreement				**0.078**

The statistical F-test for evaluating the null hypothesis (Ho: ric = 0) is obtained by dividing between-subjects variability with residual variability:

Source of Variation	Sum of Square	Deg. of freedom	Mean Square	F-test value
Between Subjects:	0.37	2	.185	**15.77**
Between Conditions:	0.00	5	0.000	
Residual:	0.12	10	0.012	
Total:	**0.49**	**17**		
Critical F-value with degrees of freedom 2 & 10 at 0.01 level:				**7.56**
Critical F-value with degrees of freedom 2 & 10 at 0.025 level:				**5.46**
Critical F-value with degrees of freedom 2 & 10 at 0.05 level:				**4.1**
Critical F-value with degrees of freedom 2 & 10 at 0.1 level:				**2.92**

Figure 5: HDM Results

Level-1	Which space agency will have the most promising future?
Financial	0.25
Scientific & Technological	0.25
Track Record	0.25
Impact	0.25
Inconsistency	0.00

Level-2	Financial	Scientific & Technological	Track Record	Impact
Average cost per mission	0.25	0.00	0.00	0.00
Expense on R&D	0.25	0.00	0.00	0.00
Total Assets	0.25	0.00	0.00	0.00
Annual Budget	0.25	0.00	0.00	0.00
Research & Development	0.00	0.38	0.00	0.00
Innovation	0.00	0.33	0.00	0.00
Reusability	0.00	0.29	0.00	0.00
Success Rate	0.00	0.00	0.33	0.00
Long Term Plans	0.00	0.00	0.33	0.00
Short Term Plans	0.00	0.00	0.33	0.00
Economy	0.00	0.00	0.00	0.33
Environmental	0.00	0.00	0.00	0.33
Future on Mankind	0.00	0.00	0.00	0.33
Inconsistency	0.00	0.00	0.00	0.00

Level-3	Average cost per mission	Expense on R&D	Total Assets	Annual Budget	Research & Development	Innovation	Reusability	Success Rate	Long Term Plans	Short Term Plans	Economy	Environmental	Future on Mankind
SpaceX	0.48	0.36	0.40	0.46	0.33	0.35	0.35	0.40	0.76	0.43	0.44	0.33	0.49
ISRO	0.28	0.36	0.34	0.22	0.33	0.36	0.37	0.35	0.13	0.38	0.30	0.33	0.28
CNSA	0.24	0.27	0.26	0.32	0.33	0.29	0.28	0.26	0.11	0.19	0.26	0.33	0.22
Inconsistency	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.03

The final result:

Level-1	Which space agency will have the most promising future?
SpaceX	0.43
ISRO	0.31
CNSA	0.26
Inconsistency	0.00

Figure 6: Expert 1 data

Level-1	Which space agency will have the most promising future?
Financial	0.10
Scientific & Technological	0.21
Track Record	0.35
Impact	0.35
Inconsistency	0.01

Level-2	Financial	Scientific & Technological	Track Record	Impact
Average cost per mission	0.47	0.00	0.00	0.00
Expense on R&D	0.16	0.00	0.00	0.00
Total Assets	0.09	0.00	0.00	0.00
Annual Budget	0.28	0.00	0.00	0.00
Research & Development	0.00	0.28	0.00	0.00
Innovation	0.00	0.14	0.00	0.00
Reusability	0.00	0.58	0.00	0.00
Success Rate	0.00	0.00	0.35	0.00
Long Term Plans	0.00	0.00	0.17	0.00
Short Term Plans	0.00	0.00	0.49	0.00
Economy	0.00	0.00	0.00	0.59
Environmental	0.00	0.00	0.00	0.25
Future on Mankind	0.00	0.00	0.00	0.16
Inconsistency	0.05	0.04	0.04	0.01

Level-3	Average cost per mission	Expense on R&D	Total Assets	Annual Budget	Research & Development	Innovation	Reusability	Success Rate	Long Term Plans	Short Term Plans	Economy	Environmental	Future on Mankind
SpaceX	0.45	0.25	0.31	0.28	0.58	0.59	0.59	0.59	0.31	0.60	0.30	0.59	0.33
ISRO	0.20	0.33	0.19	0.14	0.14	0.16	0.25	0.16	0.20	0.23	0.16	0.26	0.33
CNSA	0.35	0.43	0.50	0.58	0.28	0.25	0.16	0.25	0.50	0.17	0.54	0.15	0.33
Inconsistency	0.00	0.00	0.01	0.04	0.04	0.01	0.01	0.01	0.01	0.01	0.07	0.02	0.00

The final result:

Level-1	Which space agency will have the most promising future?
SpaceX	0.48
ISRO	0.21
CNSA	0.32
Inconsistency	0.02

Figure 7: Expert 2 data

Level-1	Which space agency will have the most promising future?
Financial	0.39
Scientific & Technological	0.28
Track Record	0.20
Impact	0.13
Inconsistency	0.01

Level-2	Financial	Scientific & Technological	Track Record	Impact
Average cost per mission	0.17	0.00	0.00	0.00
Expense on R&D	0.21	0.00	0.00	0.00
Total Assets	0.57	0.00	0.00	0.00
Annual Budget	0.05	0.00	0.00	0.00
Research & Development	0.00	0.05	0.00	0.00
Innovation	0.00	0.21	0.00	0.00
Reusability	0.00	0.75	0.00	0.00
Success Rate	0.00	0.00	0.75	0.00
Long Term Plans	0.00	0.00	0.05	0.00
Short Term Plans	0.00	0.00	0.20	0.00
Economy	0.00	0.00	0.00	0.03
Environmental	0.00	0.00	0.00	0.16
Future on Mankind	0.00	0.00	0.00	0.81
Inconsistency	0.20	0.10	0.09	0.11

Level-3	Average cost per mission	Expense on R&D	Total Assets	Annual Budget	Research & Development	Innovation	Reusability	Success Rate	Long Term Plans	Short Term Plans	Economy	Environmental	Future on Mankind
SpaceX	0.12	0.66	0.17	0.82	0.12	0.60	0.73	0.16	0.73	0.06	0.80	0.82	0.77
ISRO	0.58	0.12	0.08	0.16	0.20	0.29	0.17	0.70	0.17	0.27	0.13	0.10	0.13
CNSA	0.30	0.22	0.75	0.02	0.68	0.11	0.11	0.13	0.11	0.67	0.07	0.08	0.11
Inconsistency	0.01	0.02	0.07	0.08	0.13	0.03	0.07	0.17	0.07	0.01	0.03	0.07	0.11

The final result:

Level-1	Which space agency will have the most promising future?
SpaceX	0.44
ISRO	0.26
CNSA	0.30
Inconsistency	0.08

Figure 8: Expert 3 data

Level-1	Which space agency will have the most promising future?
Financial	0.15
Scientific & Technological	0.49
Track Record	0.10
Impact	0.25
Inconsistency	0.10

Level-2	Financial	Scientific & Technological	Track Record	Impact
Average cost per mission	0.26	0.00	0.00	0.00
Expense on R&D	0.60	0.00	0.00	0.00
Total Assets	0.04	0.00	0.00	0.00
Annual Budget	0.09	0.00	0.00	0.00
Research & Development	0.00	0.19	0.00	0.00
Innovation	0.00	0.67	0.00	0.00
Reusability	0.00	0.14	0.00	0.00
Success Rate	0.00	0.00	0.65	0.00
Long Term Plans	0.00	0.00	0.09	0.00
Short Term Plans	0.00	0.00	0.26	0.00
Economy	0.00	0.00	0.00	0.07
Environmental	0.00	0.00	0.00	0.74
Future on Mankind	0.00	0.00	0.00	0.19
Inconsistency	0.19	0.06	0.07	0.08

Level-3	Average cost per mission	Expense on R&D	Total Assets	Annual Budget	Research & Development	Innovation	Reusability	Success Rate	Long Term Plans	Short Term Plans	Economy	Environmental	Future on Mankind
SpaceX	0.02	0.64	0.73	0.64	0.80	0.73	0.97	0.26	0.98	0.43	0.67	0.23	0.98
ISRO	0.98	0.31	0.19	0.26	0.11	0.09	0.03	0.72	0.01	0.33	0.09	0.69	0.01
CNSA	0.01	0.05	0.08	0.10	0.08	0.18	0.01	0.02	0.01	0.24	0.24	0.08	0.01
Inconsistency	0.00	0.06	0.00	0.07	0.17	0.01	0.01	0.11	0.00	0.00	0.08	0.07	0.00

The final result:

Level-1	Which space agency will have the most promising future?
SpaceX	0.59
ISRO	0.30
CNSA	0.10
Inconsistency	0.06

Figure 9: Expert 4 data

Level-1	Which space agency will have the most promising future?
Financial	0.20
Scientific & Technological	0.33
Track Record	0.35
Impact	0.12
Inconsistency	0.02

Level-2	Financial	Scientific & Technological	Track Record	Impact
Average cost per mission	0.25	0.00	0.00	0.00
Expense on R&D	0.26	0.00	0.00	0.00
Total Assets	0.12	0.00	0.00	0.00
Annual Budget	0.36	0.00	0.00	0.00
Research & Development	0.00	0.18	0.00	0.00
Innovation	0.00	0.49	0.00	0.00
Reusability	0.00	0.33	0.00	0.00
Success Rate	0.00	0.00	0.45	0.00
Long Term Plans	0.00	0.00	0.36	0.00
Short Term Plans	0.00	0.00	0.19	0.00
Economy	0.00	0.00	0.00	0.22
Environmental	0.00	0.00	0.00	0.46
Future on Mankind	0.00	0.00	0.00	0.32
Inconsistency	0.04	0.15	0.00	0.01

Level-3	Average cost per mission	Expense on R&D	Total Assets	Annual Budget	Research & Development	Innovation	Reusability	Success Rate	Long Term Plans	Short Term Plans	Economy	Environmental	Future on Mankind
SpaceX	0.15	0.14	0.06	0.61	0.33	0.77	0.67	0.23	0.98	0.50	0.76	0.59	0.98
ISRO	0.46	0.30	0.15	0.29	0.33	0.18	0.31	0.75	0.01	0.32	0.11	0.32	0.01
CNSA	0.39	0.56	0.79	0.10	0.33	0.05	0.02	0.02	0.01	0.18	0.13	0.09	0.01
Inconsistency	0.00	0.00	0.01	0.01	0.00	0.03	0.08	0.13	0.00	0.02	0.00	0.00	0.00

The final result:

Level-1	Which space agency will have the most promising future?
SpaceX	0.56
ISRO	0.31
CNSA	0.13
Inconsistency	0.03

Figure 10: Expert 5 data

Level-1	Which space agency will have the most promising future?
Financial	0.10
Scientific & Technological	0.63
Track Record	0.03
Impact	0.23
Inconsistency	0.04

Level-2	Financial	Scientific & Technological	Track Record	Impact
Average cost per mission	0.32	0.00	0.00	0.00
Expense on R&D	0.42	0.00	0.00	0.00
Total Assets	0.15	0.00	0.00	0.00
Annual Budget	0.11	0.00	0.00	0.00
Research & Development	0.00	0.07	0.00	0.00
Innovation	0.00	0.70	0.00	0.00
Reusability	0.00	0.24	0.00	0.00
Success Rate	0.00	0.00	0.06	0.00
Long Term Plans	0.00	0.00	0.23	0.00
Short Term Plans	0.00	0.00	0.72	0.00
Economy	0.00	0.00	0.00	0.06
Environmental	0.00	0.00	0.00	0.75
Future on Mankind	0.00	0.00	0.00	0.19
Inconsistency	0.17	0.09	0.07	0.10

Level-3	Average cost per mission	Expense on R&D	Total Assets	Annual Budget	Research & Development	Innovation	Reusability	Success Rate	Long Term Plans	Short Term Plans	Economy	Environmental	Future on Mankind
SpaceX	0.16	0.72	0.24	0.89	0.63	0.66	0.80	0.51	0.98	0.92	0.90	0.69	0.98
ISRO	0.75	0.19	0.07	0.09	0.11	0.26	0.18	0.43	0.01	0.05	0.05	0.26	0.01
CNSA	0.09	0.10	0.70	0.02	0.27	0.08	0.02	0.06	0.02	0.03	0.04	0.05	0.01
Inconsistency	0.10	0.00	0.00	0.04	0.08	0.09	0.08	0.31	0.00	0.00	0.07	0.23	0.00

The final result:

Level-1	Which space agency will have the most promising future?
SpaceX	0.69
ISRO	0.23
CNSA	0.08
Inconsistency	0.08

Figure 11: Expert 6 data

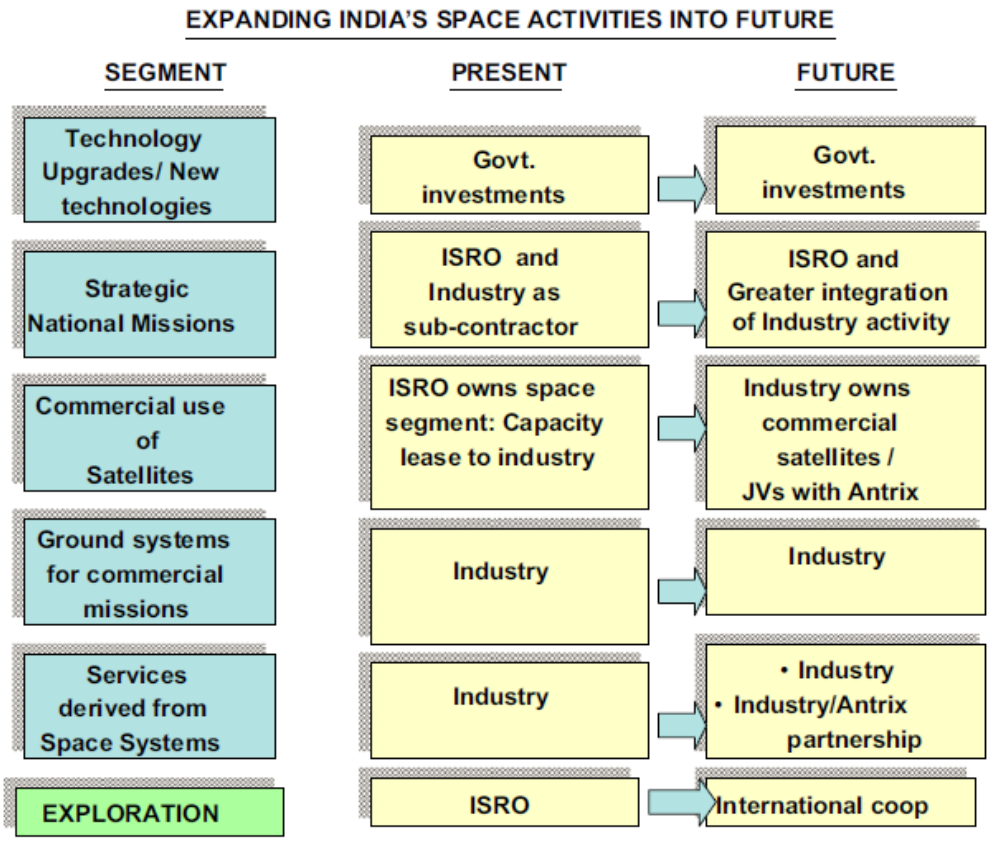

Figure 12: ISRO's strategy in expanding