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How to Find a Minimum Viable Product in IoTA

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Abstract: IoT in Aerospace sector has changed the way aerospace companies seeing the future products. As product life cycle in Aerospace & Defense industry gets longer, split-second decisions make a lot of difference between success and failure. Aerospace majors have got different plans to change the product innovation and development process by nurturing start-up culture and entrepreneurial mindset in their organization.

This investigative research is aimed in developing a methodology to identify the Minimum Viable Product (MVP) using IoT for aerospace companies. House of Quality (HoQ) has helped in identifying the positive and negative correlation between the IoT characteristics and its linkage with various aerospace systems. This exploratory research can be used by aerospace system suppliers to develop a MVP IoT product in aerospace systems.

Keywords: Internet of Things in Aerospace (IoTA), Aerospace systems, IoT Characteristics, House of Quality (HoQ), Minimum Viable Products (MVP)

1 Introduction

Aerospace and Defense (A&D) industry is poised for growth despite economic downturns. Increase in travel demand, development of new technologies and security threat for nations are fueling the increase in aircraft production, defense budgets and the need for global supply chain [1]. Airbus global market forecast predicts that air traffic will grow at 4.5% annually and more than 30,000 aircrafts will be required over the next 20 years [2]. Aircraft manufacturers and operators are always in the lookout to improve the vehicle performance by providing more connected and smarter systems to achieve the Fuel Efficiency, Zero downtime and Route optimization.

Internet of Things (IoT) is becoming more and more important in many industry sectors and domains. Digital Technology evolution is happening at a rapid pace and this will impact certainly every business. However, it is essentially a commitment by organizations to innovate which would add value to their customers. SAP research on digital transformation shows that 33% of industry leaders will be disrupted this way and 58% of companies think IoT is strategic [3]. Though the IoT evolution happened more than a decade ago, its impact on aerospace systems are limited due to IoT characteristics maturity, its adaptability and ease of implementation in safety critical aerospace systems. While there are many opportunities lined up which interests both citizen and industry, the expected benefits must abide many privacy and security challenges which are associated with the IoT. Lot of questions arise around this safety critical aerospace industry such as the vulnerability of these devices, often deployed outside a traditional IT structure that may be lacking sufficient inbuilt security. There are lack of standards and protocol in IoT infrastructure which further delay the IoT products launch [4]. Meanwhile, IEEE standards associations (IEEE P2413), International Telecommunication Union, Wireless avionics Intra-communications(WAIC) are supporting laboratory testing and coordinating the development of a Standard and Recommended Practice (SARP) through the International Civil Aviation Organization (ICAO). Aerospace major companies are developing standards and protocols using the safety by design principle for their product, so that measures to minimize cyber risks are taken early on during product R&D [5]. Hence these standards and protocols can adopt IoT in aerospace industry as well.

1.1 Objective of the paper

Aerospace industries are currently in search of minimum viable systems/products and are investing heavily to develop IoT technologies which can yield long term value. However, there is no established approach to identify MVP in IoT. The methodology developed using HoQ will help them narrow down the system/product to focus.

According to the research paper [6] findings, it is indicated that the IoT research field is immature, with experimental methods dominating the research outputs. However, paper [7] presented the IoT capabilities along with analyzing numerous related maturity models in order to build a new integrated IoT maturity model, which can be used to assess the company's level in IoT and act as a guide for advancement. There is no research paper that covers IoT characteristics maturity and its impact on aerospace systems. Therefore, objectives of this exploratory research are as follows:

1. Identification of IoTA Characteristics
2. Find out the aerospace customer pain points
3. Identify the Minimum Viable Product

1.2 IoT Potential in Aerospace

There are more than 20 IoT characteristics which can complement and add value in aerospace systems in many ways by reducing customer pain points such as flight cancellation, flight delays etc., Direct cost of air transportation delay is USD 32.9 billion which incurs a loss of USD 8.3 billion to airlines [8]. As per IATA report it is mentioned that USD 15 billion was spent on direct maintenance, with average maintenance cost of USD 295 million per airline and USD 1087 per flight

hour [9]. Identification of potential systems and its relevant characteristics maturity is the key to develop and implement IoT products/systems in aerospace. There are many potential virtual benefits awaiting post the implementation of an IoT system in aerospace, however it comes with real risks. An Overall system's vulnerability landscape is not just the mere sum of vulnerabilities of single devices. For instance, a malware on a smart phone could potentially trigger major risk in avionics systems and amplify the overall risk level [10].

1.3 Minimum Viable Product (MVP)

The Minimum Viable Product (MVP) is a product with just enough features to satisfy early customers that provides feedback for future development. Some experts suggest that in B2B, a MVP also means saleable. "It's not an MVP until you sell it. Viable means you can sell it". Gathering insights from an MVP is often less expensive than developing a product with more features, which increase costs and risk if the product happens to fail due to incorrect assumptions.

An MVP can be part of a strategy and process directed toward making and selling a product to customers. It is a core artifact in an iterative process of idea generation, prototyping, presentation, data collection, analysis and learning. One seeks to minimize the total time spent on iteration. The process is iterated until a desirable product/market fit is obtained, or until the product is deemed non-viable [11].

MVP in IoTA can create a hostile environment if we don't maintain a strong security focus, device integrity, authentication, robust user and access controls, solid encryption of data and communications [12]. As per the Avionics systems experts, IoT Characteristics such as Dynamic Changes, Connectivity, Intelligence, Expressing, Energy-Efficiency, Quality & Reliability, Cognition, Deterministic, Security and Standards & Protocols are key IoT characteristics having strong relationship with avionics systems. These IoT characteristics are aligned and complementing with Avionics engineering characteristics as well.

2 Methodology

Methodology followed in this research (see Fig. 1) was to first identify the various general IoT characteristics and its maturity in level-1. Level-2 is to find the IoT characteristics maturity using HoQ, Aerospace systems (i.e. Avionics etc.,) End user interview and IoTA Triple constraints to identify Minimum Viable Product.

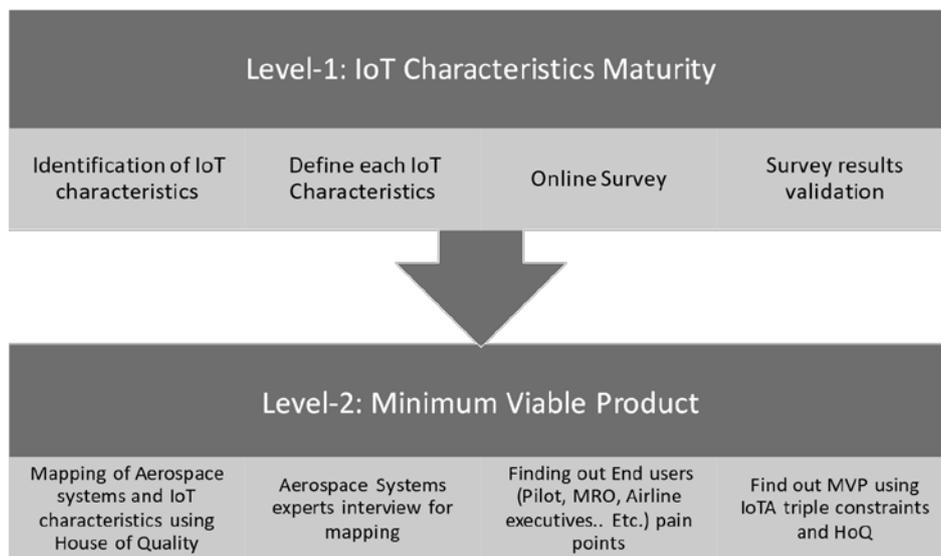


Fig.1. Step by Step methodology for MVP

2.1 Level-1: IoT Characteristics Maturity [15]

Step-1: Identification of IoT characteristics using various published papers/articles

Step-2: Definition of each IoT characteristics based on the literature survey

Step-3: Online survey

- Develop interview questions with appropriate rating scale
- Circulate the online survey to targeted IoT audience across demographics
- Plot the survey results and analyze

Step-4: Survey result validation

- Conduct IoT experts interview
- Co-relate the survey results and record findings

Limitations of Level-1

IoT characteristics definition and its understanding by survey audience, # Ratings given by audience depends on their own perspective, # IoT expert's opinion based on their industry experience may/may not align with aerospace systems

2.2 Level-2: Minimum Viable Product

Step-1: Mapping of aerospace systems and IoT characteristics using House of Quality

Step-2: Aerospace systems expert's interview for mapping in HoQ

- Interview Aerospace system experts, considering IoT characteristics and its impact on aerospace systems
- Rate the aerospace systems and its relevance with IoT characteristics

Step-3: Finding out end user (Pilots, MRO, Airline executives etc.,) pain points

- Develop survey questions with appropriate rating scale
- Circulate the online survey results to targeted aerospace system end users, Pilots, MRO, Airline executives etc.,

Step-4: Find out MVP using HoQ and IoTA triple constraints

Limitations of level-2

Aerospace System Expert's perspective on future systems using IoT is limited, # Mapping of Aerospace systems and IoT characteristics are based on available data, # IoT experts rating and the validation of results

3 IoT Characteristics Maturity

Several IoT characteristics were identified by going through various whitepapers, technical papers and articles published on Internet of Things. As these IoT characteristics have evolved over period of time, measuring its maturity is not easy from data sources. Hence decided to conduct market research using targeted IoT audience and validate the survey results by interviewing IoT experts. Online survey responses had four-point scale with radio buttons (New, Improving, Mature & Aging) to rate the characteristics maturity. Experts rate the characteristics maturity using percentage. By collating the online survey results (four points scale) with expert's percentage rating, survey results are plotted and validated as shown (see Fig. 2 & 3).

Expert-1 ratings on maturity have largely varied from survey results for the characteristics such as Heterogeneity, Safety, Connectivity, Energy efficiency, Computing/processor and Security. Whereas, IoT Characteristics such as Enormous scale, Intelligence, Configuration, Coordination, Deterministic, Mobility and Miniaturization & Composability have closely aligned rating on maturity levels with the survey results (see Fig. 2) [15]. Definition for potential Aerospace IoT Characteristics are listed in Appendix-I.

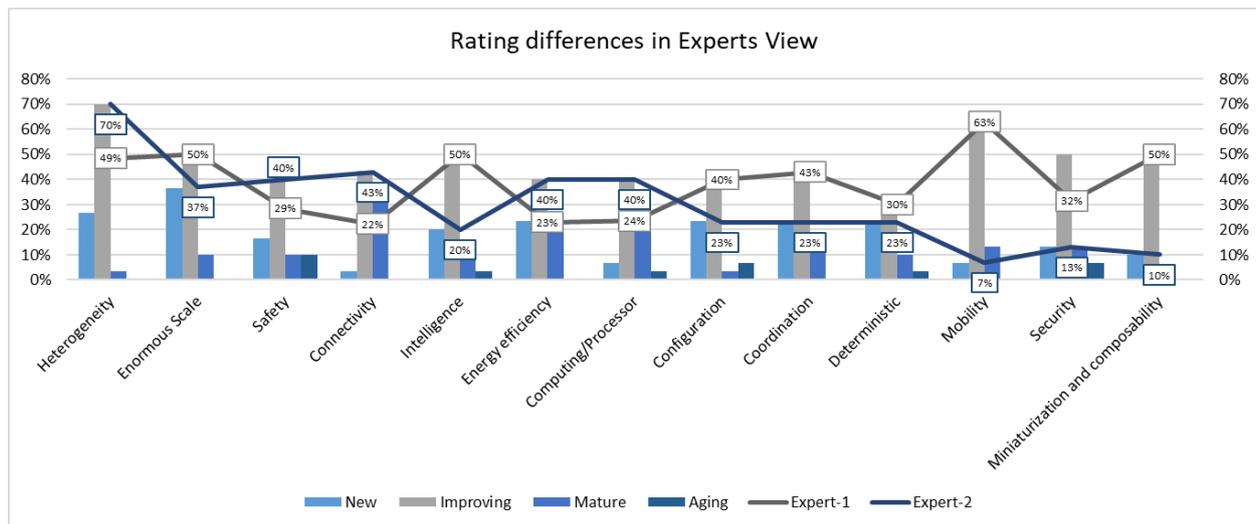


Fig.2. Differences in survey result & Experts view

As per Expert-2, Enormous scale, Intelligence, Configuration, Coordination, Deterministic, Mobility, Security and Miniaturization & Composability have different maturity ratings compared to the survey results. For IoT characteristics such as Heterogeneity, Safety, Connectivity, Energy efficiency and Computing/processor, rating of Expert-2 on maturity ratings have aligned with survey results (see Fig. 2) [15].

Similarities in ratings by experts and survey (see Fig. 3) were observed for the characteristics such as Inter-connectivity, Dynamic changes, Things related services, Sensing/Sensor, Expressing, Quality & Reliability, Cost effectiveness, Consumption, Conversion, Centralization, Cognition and Standards & Protocols

IoT Expert's rating on some of the characteristics have converged and some of them have diverged from the survey results due to their current working area and industry they represent (Expert-1 Industrial IoT, Expert-2 Aerospace IoT). Some of the IoT characteristics are totally new to aerospace, which are not the case with Industrial IoT mainly due to industry acceptance and ease of implementation.

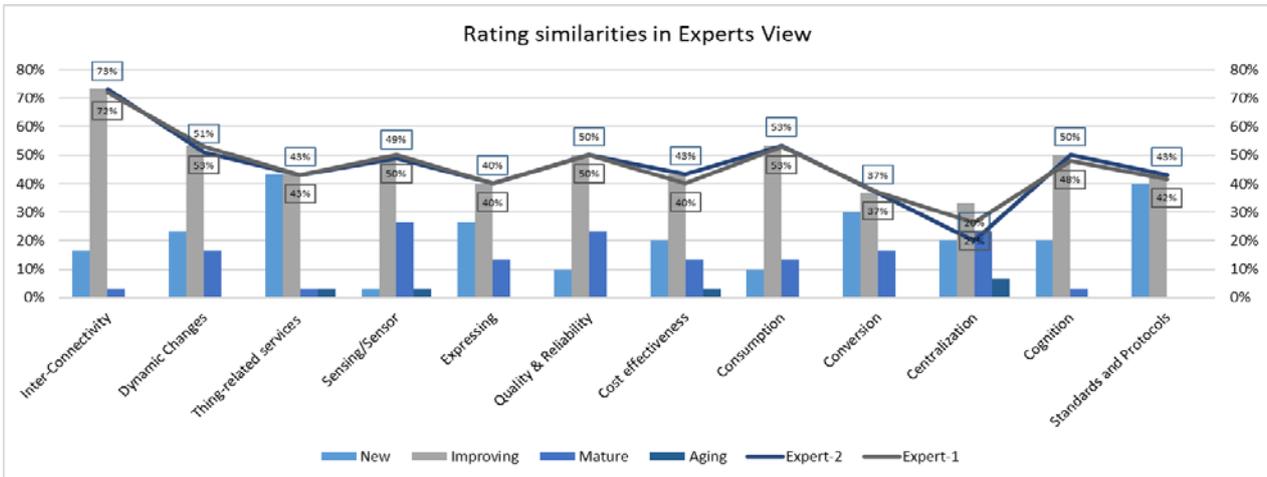


Fig.3. Similarities in survey result & Experts view

3.1 Voice of Customer

To identify the MVP, we should know what are the customer pain points and their problems. When we understand customer requirement, it is really easy to develop solution for that problem. To identify the customer's need and their pain points author conducted a survey with targeted audience who are end users of aircraft (Pilots, MRO and airline executives...etc.). The following four questions were asked. Q1 - Which aircraft systems can get impacted by IoT? Q2 - Which aircraft systems are the main reason for flight cancellation? Q3 - Which system undergoes frequent maintenance Q4 - Which aircraft system requires manual supervision? Consolidated results show that Avionics and Landing & Braking systems have scored high. These scores (see Fig. 4) are used in HoQ while filling up the weight / importance column.

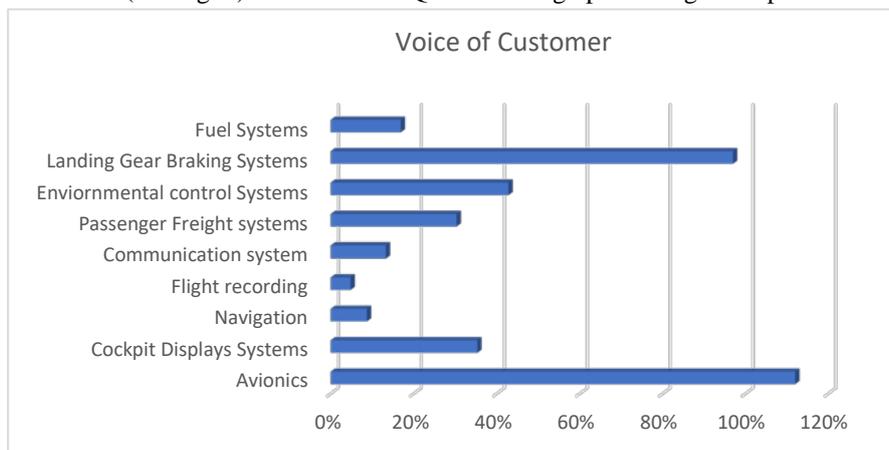


Fig.4. Voice of Customer

4 Integrating All

Quality function deployment (QFD) is a method developed in Japan, in 1966 to help transform the Voice of the Customer (VOC) into engineering characteristics for a product. Yoji Akao, the original developer, described QFD as a "method to transform qualitative user demands into quantitative parameters, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process". The house of quality was used in 1972 in the design of an oil tanker by Mitsubishi Heavy Industries [14].

The analytics and process strength of DFSS (Design For Six Sigma) are challenging, when compared with comprehensive QFD. QFD is stronger in the upfront analysis of unspoken customer needs, where DFSS is stronger in the establishment of transfer functions to deploy design parameters downstream and in establishing cost benefit analysis and capability studies. It is obvious that QFD can play strong role in identifying customer needs and the House of Quality can improve the transfer

function process by documenting many-to-many cause-and-effect relationship, their degree of contribution, and controllability. Hence QFD is an appropriate tool to obtain, analyze, and prioritize the voice of the customer which is selected for further analysis [13].

The house of quality, a part of QFD, identifies and classifies customer desires, identifies the importance of those desires, identifies engineering characteristics which may be relevant to those desires and correlates the two (desire and engineering characteristics). This process can be applied at any system composition level (e.g. system, subsystem, or component) in the design of a product and can allow for assessment of different abstractions of a system.

Customer attributes for aircraft systems are listed on the left side rows of the matrix. Global IoT characteristics are listed in the top column of HoQ. Relationship matrix (Central portion) between aircraft systems and IoT characteristics are established on a scale of strong, medium and weak relationships. Co-relationship matrix (Top Triangle) with potential positive and negative interactions between IoT characteristics has been identified. Too many positive interactions imply possible redundancy in aircraft systems IoT characteristics. Negative interactions suggest to consider the trade-offs in establishing target values for aircraft systems concepts or technology (see Fig.6).

4.1 Assumptions

Survey participant's knowledge level on IoT characteristics maturity is moderate, # Aerospace system experts understand the basics of IoT and its impact, # Selection of aerospace system is based on the research interest

Limitations

Use of HoQ alone to establish the relationship between the IoT characteristics, # Perspective of IoT impact on aerospace systems may vary among experts # IoT characteristics maturity are evolving every day, characteristics rating vary time to time, # Risk factor of using weak relationships in HoQ rows or columns, # Too many relationships between the characteristics

4.2 How to fill the HoQ

IoT Characteristics are listed in columns and aircraft systems are listed in rows (see Fig.5). Have shown only one aircraft system (Avionics) for easy understanding. Discussion with Avionics experts helped to fill the row details across Avionics with the relationship between each IoT characteristics and avionics systems. Similarly rest of the rows for all aerospace systems (rows) are filled by conducting interview with respective aerospace system experts. Tier-1 aircraft system companies' system experts (17 interviews with experience levels in the range of 10–25 years). End user views from Pilots, Maintenance Engineers & Airlines executives (3 interviews with experience levels in the range of 10–20 years) are also considered. Around 5 system relationships are not evaluated due to lack of time and are marked in red color (Fig-6, Row 9,11,14, 16 & 25). Direction of improvement of IoT characteristics (first row of detail below the triangle) and Top triangle are filled based on the author knowledge and experience as there are subjective rating. Top Triangle is filled based on the correlation between each IoT characteristic with rest of the others and are marked as strong positive, positive & negative. Correlation between IoT characteristic #1 (Interconnectivity) with characteristics #2, #3, #4 and #5 are highlighted in red(see Fig.6). Weight/importance (last but one row) is given based on the Voice of customer survey. Rest of the grey color cells are calculated values based on the data filled. Finally, the Relative weight derived is shown as the last row of detail that identifies the potential systems for IoT implementation. IoT characteristics with relative weights>4.5 (arbitrary value defined by author for this paper) have significant impact on various aerospace systems.

4.3 Results of HoQ

HoQ reveals the relative weight of the IoT characteristics (see Fig. 6). Four characteristics have scored more than 5 (Intelligence, Computing/Processor, Cognition, and Security). It would encourage companies to invest in developing technologies which can mature on these characteristics. Characteristics such as Intelligence & Computing/Processor have evolved over a period of time and have benefited other industries. It's time for aerospace industry to develop IoT products using available technologies such as computing/processor. Cognition remains as a challenge for IoT products as data is still being interpreted and perceived, as there are no guidelines established for data ownership and data economics. Currently less than 1% of data is used for decision making which drives business potential in Big data analytics. Security is another challenge for IoT in aerospace industry as the standards and protocols are still evolving and are yet to be established [15].

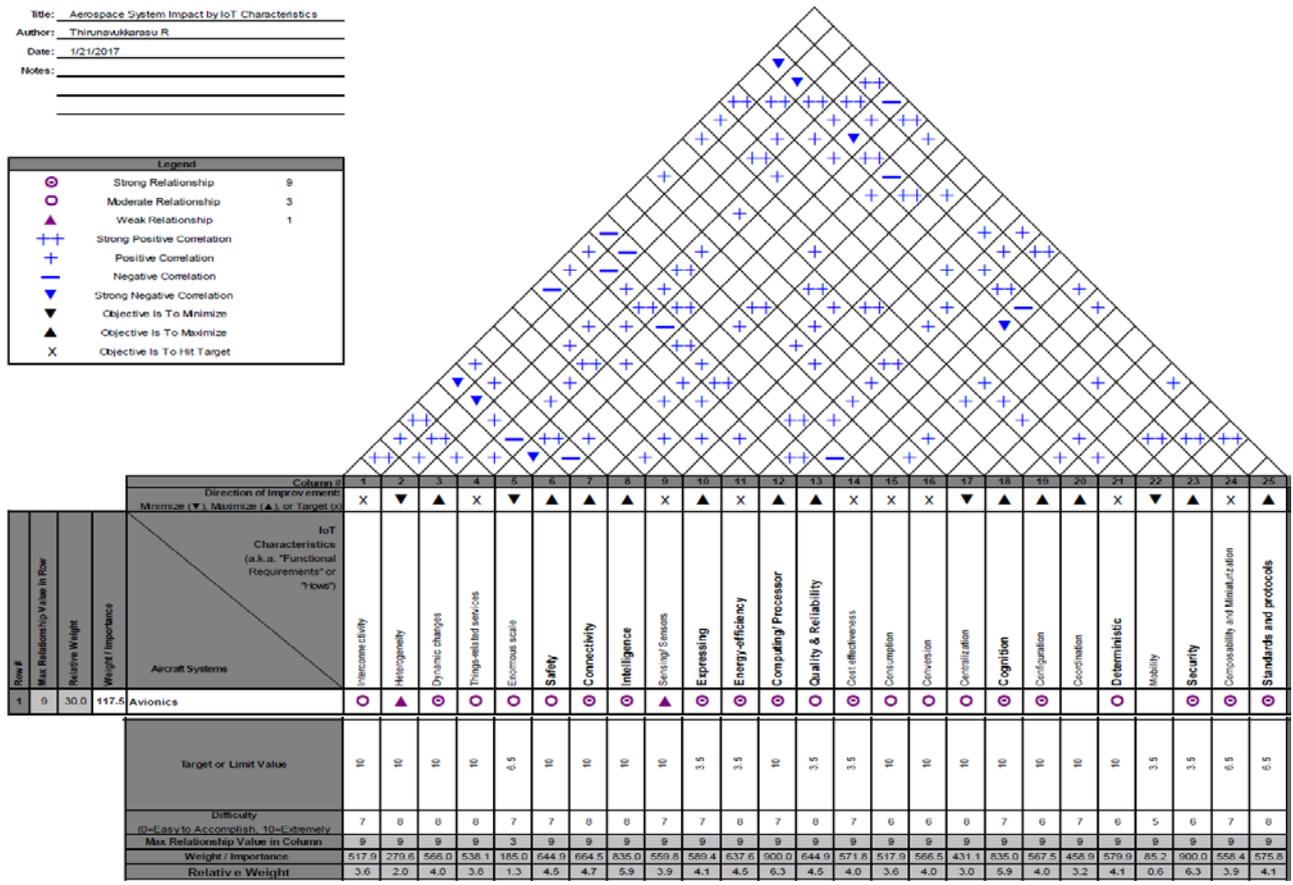


Fig.5. HoQ IoT for Avionics Systems

5 Triple Constraints

Author has considered triple constraints for developing IoT products 1. Customer pain points 2. IoT Characteristics maturity 3. Number of IoT characteristics. These three main components are key in developing IoT products for aerospace systems (see Fig. 7)

5.1 Customer Pain points

Customer pain points are classified into four categories (Flight cancellation, Flight delay, Frequent maintenance and Manual supervision). These categories are established based on the revenue loss and time spent by maintenance team. Customer pain points are gathered from VOC survey shown in section 3.1.

5.2 IoT characteristics maturity

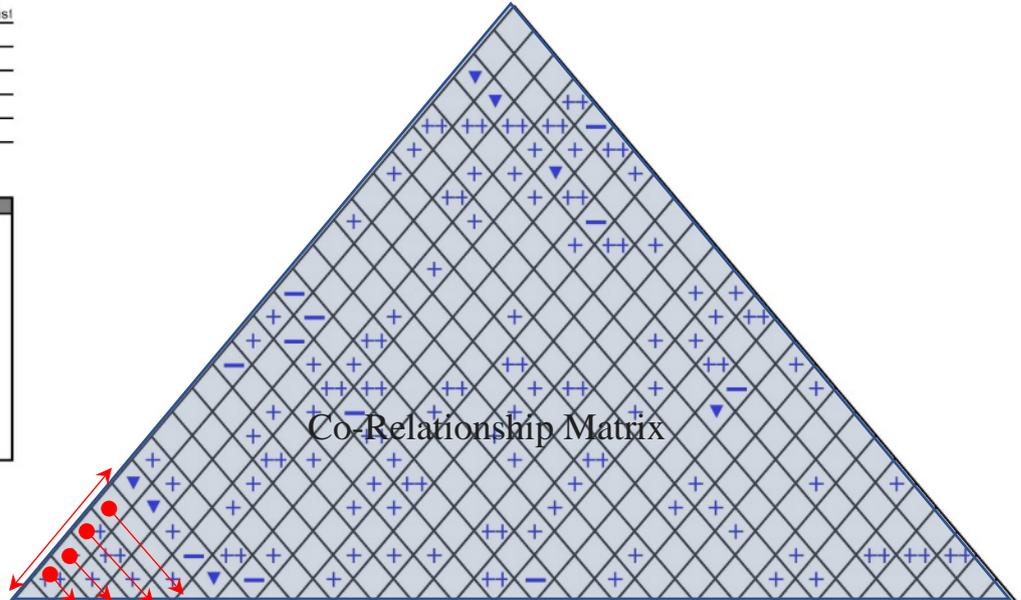
IoT characteristics maturity is measured in the scale of New, Improving, Mature and Aging. These scales are driven from product life cycle as explained in section 3. To find out IoT characteristics maturity, online survey was conducted and survey results are validated with two IoT experts. Characteristics maturity values are driven by consolidating the survey results and IoT expert's ratings.

5.3 Number of IoT Characteristics

Each system need varied number of IoT characteristics to develop/implement IoT capabilities into the system. Number of IoT characteristics are derived from results of HoQ as per section 4.3 (see Fig. 6). These characteristics have strong relationship with aerospace systems.

Title: Aerospace System Impact by IoT Characterist
 Author: Thirunavukkarasu R
 Date: 1/21/2017
 Notes:

Legend		
⊙	Strong Relationship	9
○	Moderate Relationship	3
△	Weak Relationship	1
+	Strong Positive Correlation	
+	Positive Correlation	
-	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	



Row#	Max Relationship Value in Row	Relative Weight	Weight / Importance	Aircraft Systems	IoT Characteristics (a.k.a. "Functional Requirements" or "Hows")																																																																												
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20	9	8.1	31.7	Passenger and freight systems	○	○	○	▲	▲	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	▲	○																																																			
21	9	10.8	42.4	Environmental control System	○	○	○	▲	▲	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○																																																			
22	9	0.0	0.0	Water and waste systems	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○																																																			
23	9	10.3	40.3	Fuel systems	○	○	○	○	▲	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○																																																			
24	9	24.8	97.0	Landing gear and braking systems	○	○	○	○	▲	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○																																																			
25	9	0.0	0.0	Fire protection systems	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○																																																			
				Target or Limit Value	10	10	10	10	6.5	10	10	10	10	3.5	3.5	10	3.5	3.5	10	10	10	10	10	10	10	10	3.5	3.5	6.5	6.5																																																			
				Difficulty (0=Easy to Accomplish, 10=Extremely)	7	8	8	8	7	7	8	8	7	7	8	7	8	7	6	6	8	7	6	7	6	5	6	7	8																																																				
				Max Relationship Value in Column	9	9	9	9	3	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9																																																				
				Weight / Importance	517.9	279.6	566.0	538.1	185.0	644.9	664.5	835.0	559.8	589.4	637.6	900.0	644.9	571.8	517.9	566.5	431.1	835.0	567.5	458.9	579.9	85.2	900.0	558.4	575.8																																																				
				Relative Weight	3.6	2.0	4.0	3.8	1.3	4.5	4.7	5.9	3.9	4.1	4.5	6.3	4.5	4.0	3.6	4.0	3.0	5.9	4.0	3.2	4.1	0.6	6.3	3.9	4.1																																																				

Fig.6. HoQ IoTA

Consider the customer pain point - flight cancellation, which shows customer willingness to pay as high with minimum number of required IoT characteristics which eases implementation of IoT with aging/maturing IoT characteristics. It shows the adaptability of IoT into systems which will give Minimum Viable Product (MPV) with Long Time Value (LTV). Smaller the triangle, higher the chances of launching minimum viable product with long term value for the company and adding value to the customers. Smaller triangle emerges when 1. customer pain point is flight cancellation 2. IoT Characteristics is Aging 3. Minimum number of required IoT characteristic is between 1 to 6. Flight cancellation which amounts to higher revenue loss to airlines, is one of the key pain point where the customer would be willing to pay high for such IoT system. Aging IoT characteristics means that it is a proven and matured character which can be easily implemented. Minimum number of IoT characteristics eases the implementation of IoT in aerospace systems.

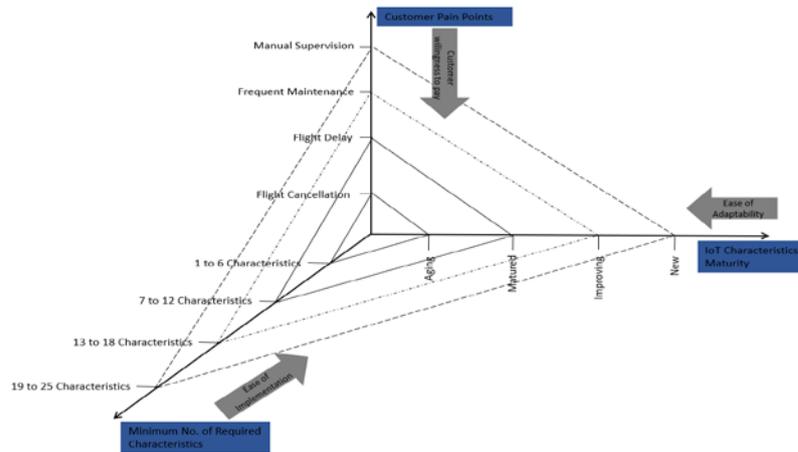


Fig.7. IoTA Triple Constraints

Smarter aero engines with health monitoring systems were developed. As the cost of electronic and computer hardware decreases, the systems are equipped with increasing numbers of sensors, detectors and computerized controllers. This additional hardware makes it possible to monitor the health of the systems with improving accuracy. Based on the reference paper [16] mapped, the triple constraints for aero engines (see Fig. 8) shows the IoT characteristics maturity score as 'Matured', with minimum number of required characteristics, around 7-12 and customer pain points scored high as any problem in engine leads to flight cancellation. As outlined earlier, smaller the triangle higher the chances of developing Minimum Viable Product. This confirms that why Engine was the first IoT product developed by Engine makers like Pratt Whitney in their Geared Turbo Fan (GTF) Engines.

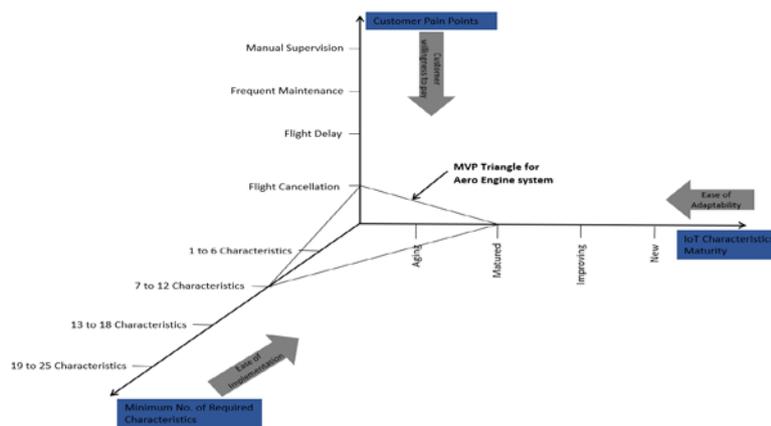


Fig.8. IoTA Triple Constraints for Aero Engines

6 Results

By plotting the customer survey results (see Fig.10), required number of IoT characteristics and its maturity level in IoTA triple constraints, we can clearly see that a minimum area of triangle emerges. This means that there is a need for developing minimum viable IoT product in landing system and braking systems with long term value. Fig. 9 shows the 13 number of characteristics ( Strong Relationship) required to implement IoT in Landing and Braking systems. As per the Voice of

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Appendix-I

Definitions of potential IoT characteristics for aerospace systems development are listed below: [15]

Safety: IoT can yield lot of benefits, however safety should be the prime concern. Design for safety is the key aspect to be considered both by creators and recipients of the IoT. This includes the safety of personal data and physical well-being.

Connectivity: It enables network compatibility and accessibility. Compatibility provides the common ability to consume and produce data while accessibility is getting on a network.

Intelligence: Product experiences are made smarter with the help of software and hardware algorithms and its computing power provides the “intelligent spark”.

Expressing: Expressing provides a way to create products that interact intelligently with people and real world, not just rendering beautiful user interface.

Energy-Efficiency: Energy harvesting, power efficiency and charging infrastructure are the necessary parts of a power intelligent ecosystem that we must design.

Computing/Processors: Certain degree of computing power is needed for all the devices connected in the network so that IoT devices can relay and transmit gathered data. Like any other computing device, this will require a processor as well.

Quality & Reliability: Devices in the IoT may be operating in extreme weather conditions and tough environments. As the IoT devices might be exposed to such an environment it is important to maintain the highest quality and reliability.

Deterministic: Time Sensitive Networking (TSN) features are currently being developed by The IEEE standards organization by including standard 802.1 and 802.3. To allow Ethernet to be deployed in mission critical applications, it is necessary to add specific features including time synchronization, scheduled traffic, ingress policing and seamless redundancy. This is to ensure that specific data traffic can flow, on time and throughout the entire network topology.

Security: This is concerned with safeguarding IoT connected devices and networks. Security is a wide concept which covers everything from authenticity, authority, integrity and confidentiality. Security paradigm will scale up when IoT would need securing the endpoints, the networks and the data moving across the network.

Standards & Protocols: A standard document has all rules and procedures developed by a regulatory party and agreed upon to be followed by many parties. A protocol is a particular set of rules that enables conversation between two computers to convey a specific set of information.

Cognition: This is the part where we make sure that we understand what the data itself means. This is not the same as plain old data conversion, this is a more analytical process where we make sure we can apply context to the data in hand