©2020 Published in 8th International Symposium on Innovative Technologies in Engineering and Science 23-25 October 2020 (ISITES2020 Bursa - Turkey)
https://doi.org/10.33793/acperpro.03.01.30

Verification of Patent Solution Proposed for Munition Release Systems Using TRIZ-Based Root Conflict Analysis (RCA+) Approach

*[1]Ayşenur Hatipoğlu, [1]Mert Subran, [1]Faik Fatih Korkmaz, [2]Metin Orhan Kaya and [3]Kemal Fidanboylu
[1]Turkish Aerospace Industries Inc., Uludag University R&D Center, Bursa, Turkey
[2]Faculty of Aeronautics and Astronautics, Istanbul Technical University, Istanbul, Turkey
[3]Faculty of Computer Engineering, Bursa Uludag University, Bursa, Turkey

Abstract:

Innovation is widely defined as transforming an idea into a new or improved method for the production of goods or services that can be sold. Many different problem-solving techniques have been developed for achieving innovative outcomes. One of these methods, which was introduced by Russian patent expert Genrich Altshuller in the 1940s, is called TRIZ. This methodology gives us a new perspective for developing solutions by formulating a problem in terms of technical and physical contradictions. It aims to evolve the systems to be more ideal by incorporating innovations. From the invention of TRIZ approach, several new tools have been developed to facilitate problem solutions. Root Conflict Analysis (RCA+) is one of the TRIZ tools, which helps extensively in analysing root contradictions of a problem. In this article, verification of patent solution proposed for munition release systems using TRIZ-Based RCA+ approach will be presented.

Key words: TRIZ, Root Conflict Analysis, RCA+, Patent Verification, Innovation, Munition Release System

1. Introduction

In developing and rapidly growing industries, companies must constantly provide new products and features to meet market needs. However, the wide variety of customer needs and the existence of many alternatives in the competitive environment inevitably brings the idea of innovation. Innovation is defined as transforming an idea into a new or improved method for the production of goods or services that can be sold. In order to produce products that can meet customer needs, solutions should be investigated for the problems of existing products or processes [1].

Many different conventional problem-solving techniques have been developed in due time; such as Trial-and-Error, Brainstorming, Synectics, Morphological Analysis, Cause-Effect Diagrams, Pareto Analysis, Distribution Diagrams, Control Charts, Histograms, Poka-Yoke Analysis. Furthermore, creative approaches such as Six Sigma Method, Quality Function Deployment (QFD), Taguchi Methods, Failure Mode and Effects Analysis (FMEA), Experimental Design have been developed [2].

A new systematic method called TRIZ was introduced by Russian patent expert Genrich Altshuller in the 1940s. TRIZ is a Russian acronym for the Theory of Inventive Problem Solving (Теория решения изобретательских задач) [3, 4]. Between 1946 and 1978, Altshuller reviewed more than 200.000 patents and identified 40.000 inventive patents among them. As a result of this, he found out that while improving one parameter of a system, another parameter was deteriorated. This formed the concept of contradiction, which established the base of TRIZ methodology. Later, he evaluated these contradictions and invented the 39x39 Contradiction Matrix and the 40 Inventive Principles. The 39x39 Contradiction Matrix and the 40 Inventive Principles brought a systematic approach to problem solving [5, 6]. In addition to the 39x39 Contradiction Matrix and the 40

*Corresponding author: Address: Turkish Aerospace Industries Inc., Uludag University R&D Center, Bursa, TURKEY. E-mail address: aysenur.hatipoglu@tai.com.tr

Inventive Principles, there are other inventive problem solving tools under the TRIZ umbrella, such as Ideality, 76 Inventive Standards, Functional Analysis, Su-Field Analysis, Little Smart People, Resource Analysis, Scientific Database, Operator STC, 9 Windows, Root Conflict Analysis (RCA+), and ARIZ (Algorithm of Inventive Problem Solving) [4].

TRIZ offers reliable methods to solve inventive problems, but it usually requires systematic and organized ways to identify problems [7]. RCA+ is one of the TRIZ tools, which uses causal relationship approach and graphically express root contradictions that cannot be easily obtained from problems [7]. These achieved root contradictions are eliminated by using TRIZ methods [8, 9].

Patents contain lots of information that can be used to enhance product innovation. TRIZ methodology can also be used for verifying the solutions proposed by the existing patents. It can also be used for finding new solutions. This method, known as patent circumvention, plays an important role in the product development industry [10 – 12]. In this article, the existing patents of munition release systems, which provide munition transport in aircraft, will be examined with RCA+ approach and the verification of the solutions of the patents with TRIZ solutions will be discussed in detail.

2. TRIZ Methodology

In conventional problem solving methods, an engineering problem is usually solved by finding a compromise solution using trial and error method. However, this method does not provide a systematic approach for solution and can cause several unsuccessful attempts. This increases time and cost of the problem solving process. Meanwhile, with the TRIZ methodology, instead of finding a compromise solution, the underlying contradictions of a problem are eliminated in order to reach an appropriate solution.

TRIZ aims to achieve the following objectives in problem solving:

- Finding an innovative solution to the problem by eliminating the existing contradictions on the system instead of a compromise solution
- Making the system more ideal
- Solving the problem by using system’s resources
- Directing the person who solves the problem to the working area
- Helping to solve the problem in less time

Contradictions are classified in two types: Technical Contradiction and Physical Contradiction [13].

2.1. Technical Contradiction

Technical contradiction is a concept in TRIZ methodology in which one or more parameters of the system improve while other parameters get worse. In this case, the main objective is to maximize the improving characteristics whereas minimizing or eliminating the deteriorating features (Figure 1).

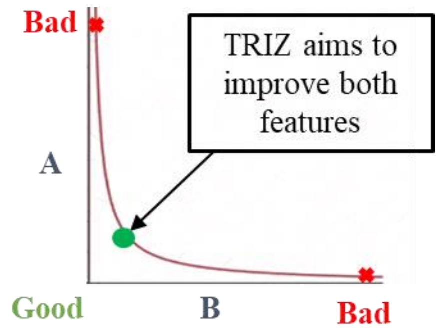

Figure 1. Technical Contradiction in TRIZ [2]

The improved and deteriorated parameters become more understandable by making technical contradiction formulation as follows (Figure 2) [2].

Figure 2. Technical Contradiction Formulation [14]

For example, to increase the speed of an aircraft, a larger-volume aircraft engine that produces more thrust force is needed, but the large-volume engine increases the weight of the aircraft. The formulation of Technical Contradiction is; if an aircraft's engine is enlarged, then the aircraft can reach higher speeds, but the weight of the aircraft increases [15].

After determining the contradiction, the appropriate Engineering parameters (Table 1) in the 39x39 Contradiction Matrix (Figure 3) are selected. The first column of the matrix refers to the improving

		Deteriorating Parameters															
		1-Weight of moving object	2-Weight of stationary object	3-Length of moving object	4-Length of stationary object	5-Area of moving object	6-Area of stationary object	7-Volume of moving object	8-Volume of stationary object	9-Speed	10-Force	11-Stress or pressure	12-Shape	13-Stability of the object's composition	…	38-Extent of automation	39-Productivity
Improving Parameters	1-Weight of moving object			15 8 29 34		29 17 38 34		29 2 40 28		2 8 15 38	8 10 18 37	10 36 37 40	10 14 35 40	1 35 19 39	…	26 35 18 19	35 3 24 37
	2-Weight of stationary object				10 1 29 35		35 30 13 2		5 35 14 2		8 10 19 35	13 29 10 18	13 10 29 14	26 39 1 40	…	2 26 35	1 28 15 35
	3-Length of moving object	8 15 29 34				15 17 4		7 17 4 35		13 4 8	17 10 4	1 8 35	1 8 10 29	1 8 15 34	…	17 24 26 16	14 4 28 29
	4-Length of stationary object		35 28 40 29				17 7 10 40		35 8 2 14		28 10	1 14 35	13 14 15 7	39 37 35	…		30 14 7 26
	5-Area of moving object	2 17 29 4		14 15 18 4				7 14 17 4		29 30 4 34	19 30 35 2	10 15 36 28	5 34 29 4	11 2 13 39	…	14 30 28 23	10 26 34 2
	6-Area of stationary object		30 2 14 18		26 7 9 39						1 18 35 36	10 15 36 37		2 38	…	23	10 15 17 7
	7-Volume of moving object	2 26 29 40		1 7 4 35		1 7 4 17				29 4 38 34	15 35 36 37	6 35 36 37	1 15 29 4	28 10 1 39	…	35 34 16 24	10 6 2 34
	8-Volume of stationary object		35 10 19 14	19 14	35 8 2 14						2 18 37	24 35	7 2 35	34 28 35 40	…		35 37 10 2
	9-Speed	2 28 13 38		13 14 8		29 30 34		7 29 34			13 28 15 19	6 18 38 40	35 15 18 34	28 33 1 18	…	10 18	
	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	.	⋮	⋮
	39-Productivity	35 26 24 37	28 27 15 3	18 4 28 38	30 7 14 26	10 26 34 31	10 35 17 7	2 6 34 10	35 37 10 2		28 15 10 36	10 37 14	14 10 34 40	35 3 22 39	…	5 12 35 26	

Figure 3. 39x39 Contradiction Matrix

parameters and the first row refers to the deteriorating parameters. The intersections of a column and row represents the relevant Inventive Principles for a contradiction.

Table 1. 39 Parameters of the Contradiction Matrix

No	Parameter Name	No	Parameter Name
1	Weight of moving object	21	Power
2	Weight of stationary object	22	Loss of energy
3	Length of moving object	23	Loss of substance
4	Length of stationary object	24	Loss of information
5	Area of moving object	25	Loss of time
6	Area of stationary object	26	Quantity of substance/the matter
7	Volume of moving object	27	Reliability
8	Volume of stationary object	28	Measurement accuracy
9	Speed	29	Manufacturing precision
10	Force	30	External harm affects the object
11	Stress or pressure	31	Object-generated harmful factors
12	Shape	32	Ease of manufacture
13	Stability of the object's composition	33	Ease of operation
14	Strength	34	Ease of repair
15	Duration of action by a moving object	35	Adaptability or versatility
16	Duration of action by a stationary object	36	Device complexity
17	Temperature	37	Difficulty of detecting and measuring
18	Illumination intensity	38	Extent of automation
19	Use of energy by moving object	39	Productivity
20	Use of energy by stationary object		

2.2. Physical Contradiction

A physical contradiction is a concept in TRIZ methodology in which the opposite states of any feature of the system are desired to occur simultaneously. Physical Contradictions can be solved by using Separation Principles which have four different types: separation in time, separation in space, separation between conditions, separation between the whole system and its parts (Figure 4).

For example, the landing gear of the aircraft is used only during landing and taking-off. Fixed landing wheels causes more fuel consumption due to friction. Therefore, the landing gear should be present at the time of landing and taking-off, but should be absent at the time of flight. The principle of separation in time is used when the feature is required to be present in a period but absent in another period. Contradiction is eliminated by the retractable landing gear using the principle of *Nested Doll* (7) which is suggested by the principle of separation in time [15].

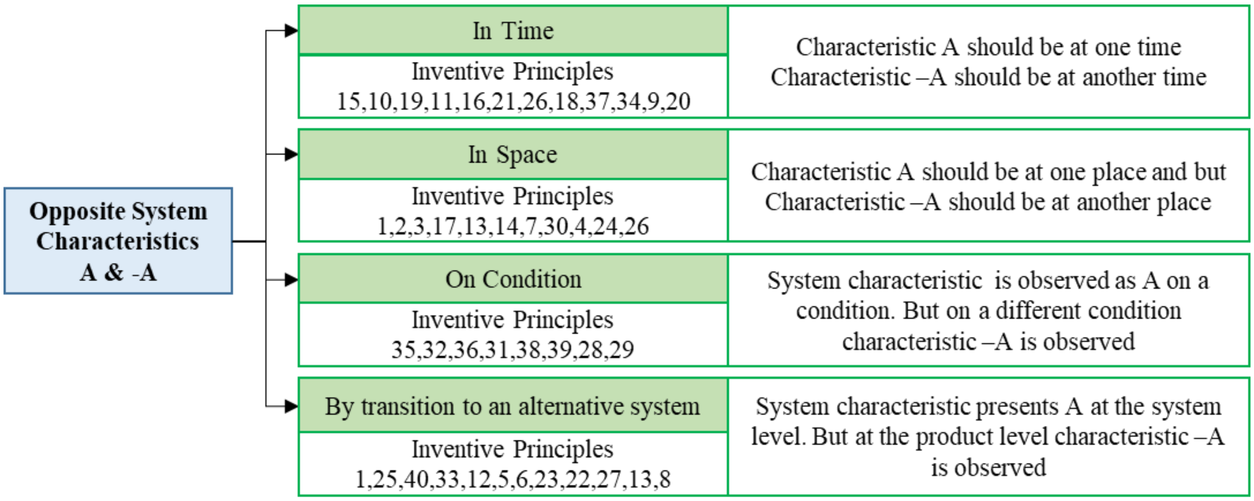

Figure 4. Separation Principles and suggested Inventive Principles [16]

After determining the type of contradiction, the Inventive Principles, which are proposed from the separation principles or the contradiction matrix, are achieved. A creative solution is obtained by working on those principles which are shown in the following Table 2.

Table 2. 40 Inventive Principles

No	Principle Name	No	Principle Name
1	Segmentation	21	Rushing Through
2	Taking out	22	Blessing in Disguise
3	Local quality	23	Feedback
4	Asymmetry	24	Intermediary
5	Merging	25	Self-Service
6	Universality	26	Copying
7	Nested Doll	27	Cheap Short-Living Objects
8	Anti-Weight	28	Replace Mechanical System
9	Prior Counteraction	29	Pneumatics and Hydraulics
10	Prior Action	30	Flexible Membranes
11	Cushion in Advance	31	Porous Materials
12	Equipotentiality	32	Color Change
13	The Other Way Round	33	Homogeneity
14	Spheroidality – Curvature	34	Discarding and Recovering
15	Dynamics	35	Parameter Change
16	Partial or Excessive Action	36	Phase Transition
17	Another Dimension	37	Thermal Expansion
18	Mechanical Vibration	38	Accelerated Oxidation
19	Periodic Action	39	Inert Atmosphere
20	Continuity of Useful Action	40	Composite Materials

3. Root Conflict Analysis (RCA+)

Before solving technical problems, it is hard to recognize contradiction in some complex cases. Commonly used methods, such as Fishbone Diagrams, Root Cause Analysis, Method of Five Why's, Current Reality Trees, help to define problems. However, they are not useful for finding the root contradiction of the problem [7, 17, 18]. RCA+ tool guides us to achieve the root contradiction behind the negative effect methodically [9].

The causal relationships approach can significantly assist in defining a problem correctly from the first step of the problem analysis. Therefore, RCA+ starts by stating a general negative effect. We can find all possible reasons by asking, "What causes this effect to occur?" [7, 17]. The general structure of cause and effect chain can be seen in Figure 5.

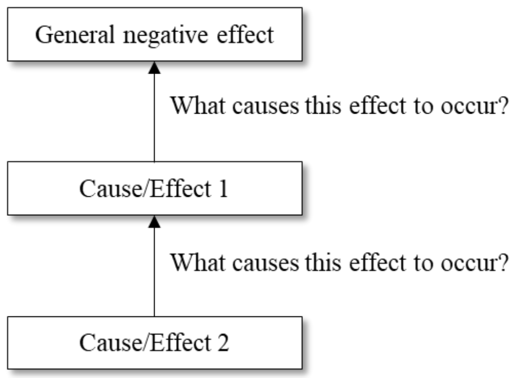

Figure 5. The general structure of a cause and effect chain [8]

An answer to cause question has to identify which situation is responsible for generating the negative effect accurately. Then, the cause statement is added to the RCA+ Diagram using unique RCA+ symbols as shown in Figure 6.

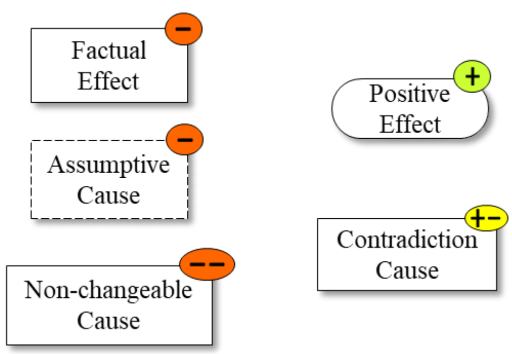

Figure 6. RCA+ Symbols [9]

The answer should not only contain an object but also identify physical parameters relative to the effect. It should always be checked that if the answer is enough to identify the negative effect. It is also possible to have different causes, which generate the same effect. If there are other causes, they should be added to the RCA+ Diagram with using "AND" or "OR" relationship. In "AND" relationship, if there are additional causes interrelated with negative effect, only the solution of one contradiction of the branch is enough to solve the problem (Figure 7a). On the other hand, if there are independent reasons, they should be added to the Diagram using "OR" relationship (Figure 7b). All relationships, which are added with OR symbol, should be solved separately [7].

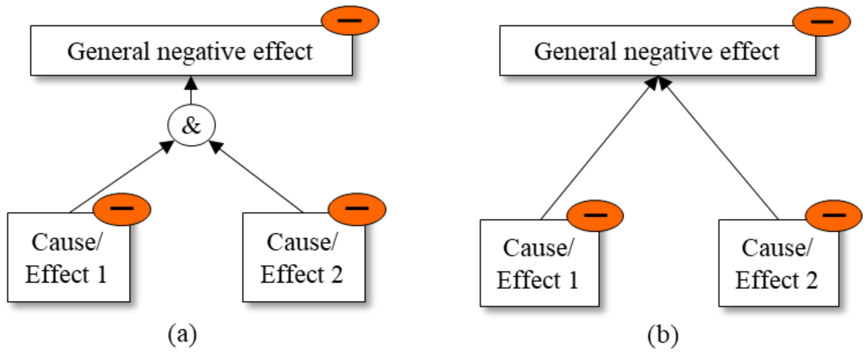

Figure 7. AND and OR Relationships on RCA+ Diagram

The questioning progress continues until the root contradiction of the problem is obtained. The root contradiction includes a positive and a negative effect [7, 8]. Typical Structure of this type of situation can be seen in Figure 8. After a contradiction cause is handled, TRIZ method can be applied to obtain the suggested Inventive Principles.

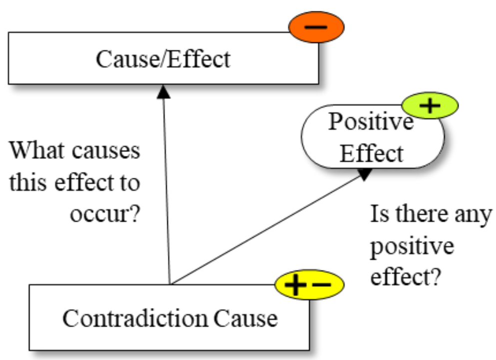

Figure 8. Contradiction Cause on RCA+ Diagram [8]

The applicability of RCA+ was investigated and tested as a method to solve and analyze both technological and business problems [7]. Compared to other methods, RCA+ has produced better results to identify contradictions systematically. In this study, a patented creative solution for release mechanisms [19] has been analyzed with RCA+ Diagram.

4. Case Study: Verifying Patent Solutions by using TRIZ and RCA+ Methods

Store suspension and release equipment are used for attaching munitions and stores to the military aircrafts. Different loads in an aircraft can be transported by pylons, release mechanisms, launchers, multiple munition carriers or adapter systems. The release mechanisms are used to safely separate any munition carried by the aircraft [20].

Release mechanisms are divided into three categories: pyrotechnic, pneumatic and electromechanical release systems. Pyrotechnic release system uses explosive materials for generating the munition ejecting force, whereas the pneumatic release system uses high-pressure gas and electromechanical release systems are used through a mechanical actuator which is controlled by electronic equipment.

In this article, a problem have been analyzed using TRIZ and RCA+ methods which arises from the failure of the releasing mechanism [19]. Negative effects stated in the patent have been identified by examining the release mechanism phenomenon. Different undesirable effects have been observed from the main problem such as; long time for device replacement and low operating reliability of the ejection mechanism. Figure 9 shows the flow chart of the TRIZ approach, which is used for solving undesirable effects of the problem in this case study.

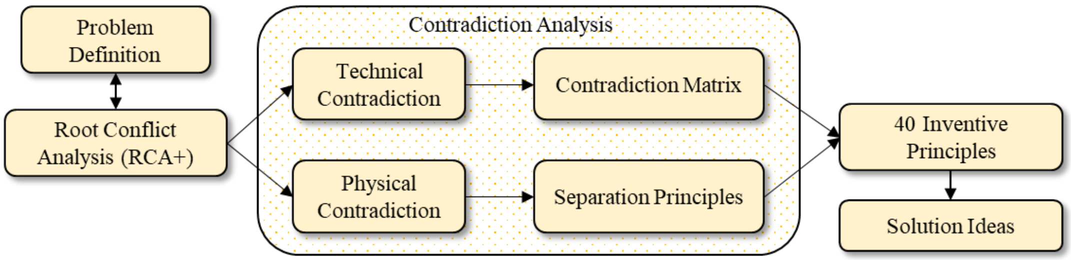

Figure 9. TRIZ solution flow chart

4.1. Root Conflict Analysis (RCA+)

It might be desirable to carry munitions with different sizes, weights, and geometries in military aircraft. Conventional carriage and ejection mechanisms are designed for a single type of store in order to reduce the complexity of the device. However, this design requires replacing the release mechanism in case of loading a new type of store, which takes a long time. Also, using cartridge actuated devices in release systems have risks because of the volatile nature of cartridges [19].

In Figure 10, the problem of “Release system does not work as desired” has been examined with RCA+ using information accessible in the US 2006108478A1 patent [19].

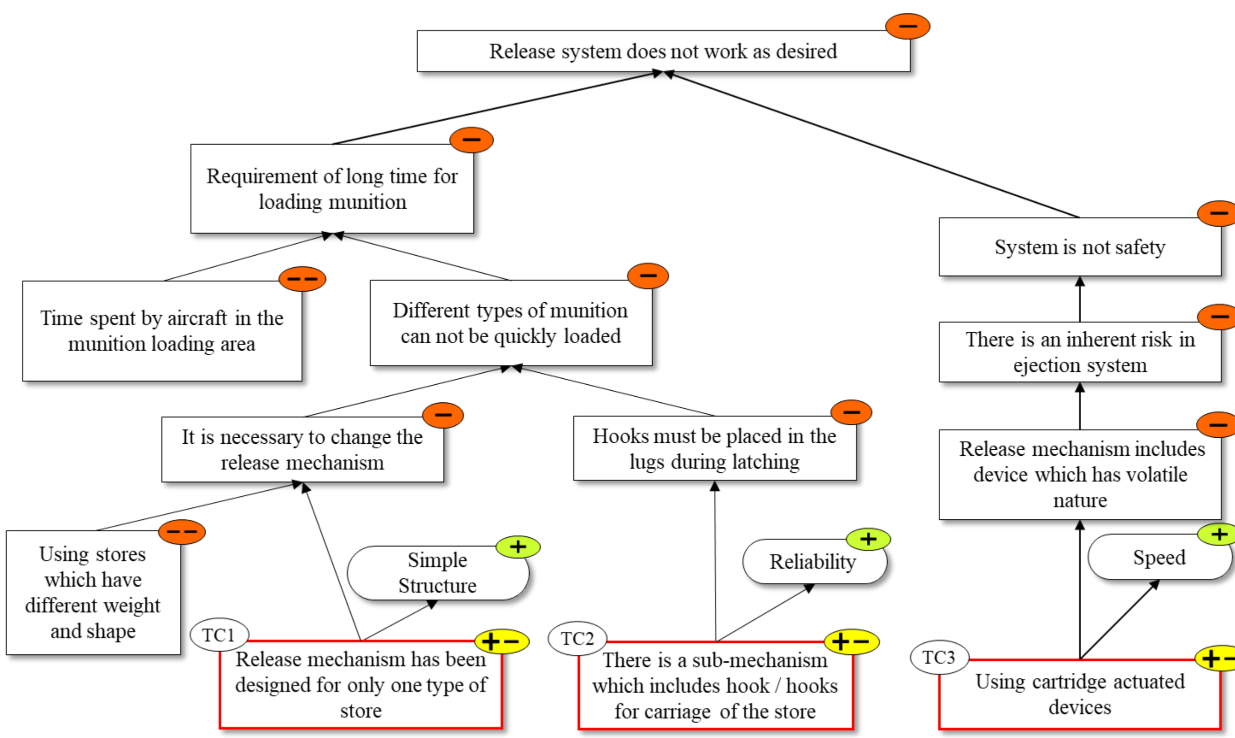

Figure 10. RCA+ Diagram of the problem

4.2. Technical Contradictions

The Technical Contradictions from RCA+ (see Figure 10) have been listed in Table 3.

Table 3. Contradiction table prepared from the RCA+ Diagram

No	Contradiction	Negative Effect	Positive Effect
1	Designing the mechanism for only one store type	Replacing the device requires long time.	Structure of the device is simple.
2	A sub-mechanism which includes hook / hooks for the carriage of the store	Replacing the device requires long time.	The reliability of the mechanism is improved.
3	Using cartridge actuated devices	The cartridge has a volatile nature.	Ejection of the store is quick.

Technical Contradiction 1: If the release mechanism is designed for only one store type, then the structure of the device will be simple, but replacing the device will take long time.

- Improving Parameter: Loss of time (25)
- Worsening Parameter: Device complexity (36)

Technical Contradiction 2: If there is a sub-mechanism that includes hook / hooks for carriage of the store, then the reliability of the mechanism will be improved, but replacing the device will take long time.

- Improving Parameter: Loss of time (25)
- Worsening Parameter: Reliability (27)

Technical Contradiction 3: If cartridge actuated devices are used for the release of the munition, then ejection of the store will be quick, but nature of the cartridge has many risks.

- Improving Parameter: Reliability (27)
- Worsening Parameter: Speed (9)

4.3. Inventive Principles

Suggested Inventive Principles have been listed in Table 4.

Table 4. Using Contradiction Matrix and obtained Inventive Principles

No	Improving Parameter	Worsening Parameter	Inventive Principles
1	Loss of time (25)	Device complexity (36)	Universality (6) Pneumatics and Hydraulics (29)
2	Loss of time (25)	Reliability (27)	Prior Action (10) Flexible Shells & Thin Films (30) Asymmetry (4)
3	Reliability (27)	Speed (9)	Rushing Through (21) Parameter Change (35) Cushion in Advance (11) Replace Mechanical System (28)

4.4. Solution Ideas

In this part, the suggested Inventive Principles are adapted to a specific problem solution. Solution ideas have been listed below.

Solution Idea 1: In Technical Contradiction 1, the problem was long process time requirement for replacing the release unit. To avoid this problem, a push arm, which is suitable for different type of stores, can be used by adapting the Universality (6) Principle. Only relevant changes are made to this push arm instead of replacing release mechanism when loading different types of munition. Figure 11 shows a sway brace design as a push arm in the patent. The system becomes compatible to various types of munitions by adding adjustment elements to the sway brace [19].

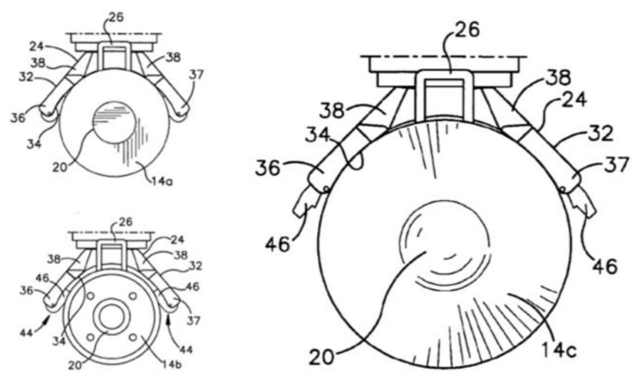

Figure 11. A suitable sway brace for different types of munition [19]

Solution Idea 2: In Technical Contradiction 2, the problem was replacement of the release unit that requires long time. To avoid this problem, hooks can be designed independently of each other by adapting the Asymmetry (4) Principle (Figure 12). Thus, munitions that have a single hook can also be loaded by deactivating one of the two hooks as necessary [20]. In addition, we can approach to this problem from Physical Contradiction perspective. If we look at the Principle of Separation in Space, Asymmetry (4) could be obtained.

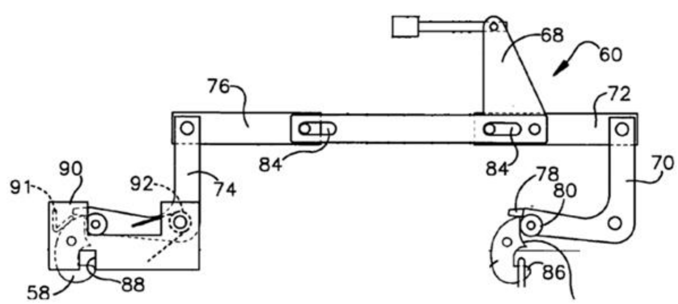

Figure 12. Independently movable hooks of the release mechanism [19]

Solution Idea 3: In Technical Contradiction 3, the problem was the risks in using a cartridge with volatile nature. To avoid this problem, a push arm actuated by a solenoid or motor driven member can be used by adapting the principle of Replace Mechanical System (28). However, in the patent [19], the piston, which can be fluid driven instead of explosive systems, drives the movable push arm by adapting the principle of Parameter Change (35). Figure 13 shows the patent drawing of this structure [19].

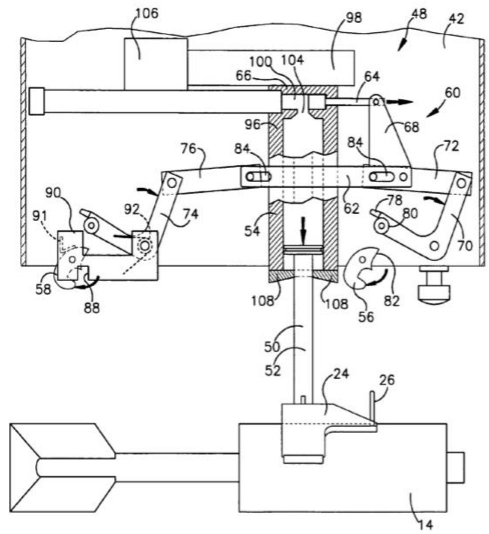

Figure 13. A release mechanism driven by fluid pressure [19]

5. Conclusion

In this article, an overview on TRIZ Technical and Physical Contradiction, 39x39 Contradiction Matrix and 40 Inventive Principles has been explained in detail. The RCA+ tool, which helps in finding the root contradictions in complex problems, has been examined and discussed with a case study on munition release systems.

The existing patent of a release mechanism, which provide munition transport and ejection in aircraft, have been analyzed. As a result of this case study, two main problems have been detected. These problems are long device replacement process and low operating reliability of the release mechanism. Three different technical contradictions in the patent have been found by analyzing the negative effects using RCA+ tool. For these contradictions, three different solutions have been proposed by using TRIZ.

The first contradiction is designing the release mechanism for only one store type; this makes the structure of the device simple but replacement of the device takes long time. A push arm, which is suitable for different type of stores, is suggested by applying TRIZ method. The next contradiction is having a sub-mechanism that includes hook or hooks for carriage of the store; this improves the mechanism, but replacing the device takes long time. Independent hooks can be designed by applying TRIZ method. The last contradiction is using cartridge actuated devices; this results in a faster ejection of the store but nature of the cartridge has many risks. Liquid or gas pressure systems can be used by applying TRIZ method.

Consequently, inventive patent solution has been verified using TRIZ and RCA+ methods for munition release systems on military aircrafts.

6. References

[1] Czinki A, Hentschel C. Solving complex problems and TRIZ. Procedia CIRP 2016; 39:27-32.

[2] Cerit B, Küçükyazıcı G, Şener D. TRIZ: Theory of Inventive Problem Solving and Comparison of TRIZ with the other Problem Solving Techniques. Balkan Journal Of Electrical & Computer Engineering 2014; 2(2):66-74.

[3] Terninko J, Zusman A, Zlotin B. Systematic innovation: an introduction to TRIZ. Boca Raton: St. Lucie Press; 1998.

[4] Barry K, Domb E, Slocum MS. What is TRIZ. The TRIZ Journal 2010.

[5] Gadd K. TRIZ for engineers: enabling inventive problem solving. West Sussex: John Wiley & Sons; 2011.

[6] Hanies-Gadd L. TRIZ for Dummies. Chichester: John Wiley & Sons; 2016.

[7] Souchkov V. Root Conflict Analysis (RCA+): Structured problems and contradictions mapping. Proceedings of the ETRIA TRIZ Future Conference 2005.

[8] Souchkov V. Application of Root Conflict Analysis (RCA+) to formulate inventive problems in the maritime industry. Zeszyty Naukowe Akademii Morskiej w Szczecinie 2017; 51(123):183-186.

[9] Souchkov V. A Guide to Root Conflict Analysis. The Netherlands ICG Training & Consulting, Enschede, 2011 [Online]. Available: http://www.xtriz.com/publications/RCA_Plus_July2011.pdf

[10] Zanten V, Veldhuijzen F, Wessel WW. Patent circumvention strategy using TRIZ-based design-around approaches. Procedia Engineering 2015; 131: 798-806.

[11] Liang Y, Tan R, Ma J. Patent analysis with text mining for TRIZ. The IEEE International Conference on Management of Innovation and Technology 2008; 1147-1151.

[12] Cheng ST, Yu WD, Wu CM, Chiu RS. Analysis of construction inventive patents based on TRIZ. Proceedings of International Symposium on Automation and Robotics in Construction, ISARC 2006; 134-139.

[13] Rantanen K, Domb E. Simplified TRIZ: New problem-solving applications for engineers and manufacturing professionals. New York: Auerbach Publications; 2002.

[14] Rantanen K, Conley DW, Domb ER. Simplified TRIZ New Problem-Solving Applications for Technical and Business Professionals. 3rd ed. New York: Taylor & Francis; 2018.

[15] Altshuller G, Shulyak L, Rodman S. 40 Principles: TRIZ Keys to Technical Innovation (Triztools). Worcester: Technical Innovation Center INC; 2005.

[16] Mann D, Physical Contradictions: Solving or Managing, the TRIZ Journal

[17] Baharoma MZ, Delbressine F, Toeters M, Feijs L. The identification of contradictions in cliff: an automatized zipper prototype using the TRIZ method with Root Conflict Analysis (RCA+). Proceedings of the 13th International MATRIZ Conference TRIZfest 2017; 407-418.

[18] Souchkov V, Hoeboer R, Zutphen M. TRIZ in business: application of RCA+ to identify and solve conflicts related to business problems. Proceedings of the ETRIA TRIZ Future Conference 2006; 1-8.

[19] Ronaldo B, Benjamin G, Armando G. Assembly for carrying and ejecting stores. U.S. Patent 2006108478A1, May. 25, 2006.

[20] Airborne Stores Suspension Equipment and Aircraft-Store Interface (Carriage Phase), MIL-STD-8591, 2005.