

The Rules of Preventing Collisions in Outer Space

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Abstract

Recently, SpaceX announced that it would send passengers to the moon in 2018. With the new round of space exploration boom, national research institutions, commercial enterprises are committed to the study of more advanced and economical spacecraft to explore and develop outer space. As a result, more spacecraft will be launched into space. Therefore, it is necessary to establish a system of traffic rules for navigation in outer space.

Although different modes of transport follow different traffic rules, however, many of these traffic rules are similar. The rules of preventing collisions in outer space should also be similar to other rules of preventing collisions in basic principles and measures to preventing collisions. This is not only the consideration of the efficiency of making rules, but to consider the coordination of navigation in outer space and air navigation, because the navigation in outer space and air navigation are not two independent concepts. As a representative of a type of spacecraft designed for space travel, SpaceShipTwo, the spacecraft of Virgin Galactic, has both the characteristics of spacecraft and aircraft. This type of aircraft is similar to a seaplane, which could both navigation in water and air. While a seaplane is navigating in water, it follows the rules of water navigation, such as the 2005 COLREGS, while this seaplane navigating in the air, it follows the rules of air navigation.

It seems to increase the burden of the pilot that demand a seaplane to follow different rules of preventing collisions in the water or the air. However, Because of the similar basic principles and measures to preventing collisions in both rules of water navigation and air navigation, this worry seems to be misplaced.

This paper will first address the commonality in all modes of traffic rules. Especially the basic principles and measures to preventing a collision. It will list the essential principles and measures in air navigation, and study whether these principles and measures can be applied to air navigation. Finally, the paper will address the problems may be involved in the air traffic management while spacecraft are navigating in the air.

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1. Setup the legal system of “Civil aerospace activities”

In recent years, many commercial companies to invest in the space industry, with the progress of technology. The commercial aerospace operation is no longer limited to launching satellites, transporting goods. Commercial manned space technology is becoming more mature.

While commercial entities carry out civil aerospace activities, Now, the industry needs to face a problem: Whether it is necessary to build up the legal system of “Civil aerospace activities”? After analysis of status and development trend of the industry, and contrast with the progress of air law and maritime law There is a definite answer to the problem above.

Firstly, it is necessary to distinguish between civil aerospace activities from state aerospace activities legally. Civil aerospace activities trends of internationality shall not be ignored. For instance, a commercial spacecraft might transport people of multiple nationalities, and be launched or recovered different states, Navigating in the airspace of different states. However, it's hard to define the usability of some aerospace activities, such as launch and operate remote sensing satellites or navigation satellites, because of their multiple usability that can both serve commercial entities and military. When a state cannot define the usability of a commercial spacecraft, it may reject the application for entrance to the territory of this spacecraft.

Thus, an explicit definition of the usability of the commercial spacecraft will help the operator apply for the permit of navigation, takeoff or landing permits, and Business license with less legal procedure costs. It will promote the progress of commercial aerospace industry.

Secondly, the commercial aerospace industry needs systematized legislation which is different from current international space law. The Outer space treaty, the Moon agreement, were born in the age of The Space Race, focus on the state aerospace activities, and setup some basic rule of peaceful expiration and use the out space. The provisions of the treaties mentioned above do not involve the operating regulation of commercial aerospace activities, such as international business arrangements, safety regulations, the allocation of right and obligations between states, commercial entities and customer. The provisions of procedures cannot settle disputes of commercial aerospace activities either because the procedures are designed for settle dispute between states.

The relationship between space law and the legal system of “Civil aerospace activities” is like that of law of the sea (i.e. the United Nations Convention on the Law of the Sea of 10 December 1982) and maritime law (e.g. International Convention for the Unification of Certain Rules of Law Relating to Bills of Lading, 1924, International Convention for Safety of Life at Sea, 1974). The law of the sea mainly to solve the problem of exploration and use of the human public domain. The maritime law mainly deals with the civil

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entities how to operate in these public areas. This relationship can also be found in air law.

Consequently, it is the time to build up a legal system of “Civil aerospace activities”. After Compare of the structure of maritime law and air law, legal system of “Civil aerospace activities” could be divided into two parts: one is the regulation of navigation, which can also be called “Safety Rules”, another one is the allocation of right and obligations, which can also be called “Business Rules”. These two parts may involve a lot of legislation, and this note selects the rules of preventing collisions for further discussion, which is an important part of “Safety Rules” of “Civil aerospace activities.”

2. The Commonality in the Rules of Preventing Collisions

2.1 The Zone determines the Rules of Preventing Collisions

It is worth noting that either in the rules of preventing collisions in water navigation, rules of air navigation or rules of road traffic, the basic rules of preventing collision are not based on the type of vehicle but based on the zone where the vehicles are operating.

For example, according to the Rule 1 of International Regulations for Preventing Collisions at Sea(COLREGS), Version 9.4, 2005, the 2005 COLREGS shall apply to all vessels upon the high seas and in all waters connected in addition to that navigable by seagoing vessels.¹ And the Paragraph (a) of Rule 3 of 2005 COLREGS defined vessel, including every description of water craft, including non-displacement craft, WIG craft, and seaplanes, used or capable of being used as a means of transportation on water.² The Rule 18 of 2005 COLREGS also provided even a vehicle could navigation in air or land, such as seaplane and hovercraft, the operator shall observe 2005 COLREGS while operating this vehicle in high seas.³ Consequently, The term “vessel” used in the 2005 COLREGS is an open

1 Paragraph (a), Rule 1 Application, the 2005 COLREGS.

2 Paragraph (a), Rule 3 General definitions, the 2005 COLREGS.

3 Paragraph (e) and Paragraph (f), Rule 18 Responsibilities between vessels, the 1972 COLREGS. The Paragraph (e) of Rule 18 provided that “A seaplane on the water shall, in general, keep well clear of all vessels and avoid impeding their navigation. In the circumstances, however, where a risk of collision exists, she shall comply with the Rules of this part.” This Rule focuses on the stage while a seaplane navigation in water does not apply to the stage in a seaplane navigation in the air.

The Paragraph (f) provided that “(i). A WIG craft shall when taking off, landing and in flight near the surface, keep well clear of all other vessels and avoid impeding their navigation; (ii). A WIG craft operating on the water surface shall comply with the Rules of this Part as a power-driven vessel.” In practice, some WIGs can leave the surface of the water and navigation in air or travel on lands, such as hovercraft and ground-effect vehicle. This Rule also focuses on the stage while a WIG navigation in water does not apply to the stage in a WIG navigation in air or travel on land.

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concept. In the future, there will be more vehicles with water navigation capabilities, those vehicles that meet the general characteristics of navigation in the high sea will be included in the definition “vessel” of 2005 COLREGS. A similar definition can also be found in the rules of preventing a collision in air navigation. According to the Chapter 1. Definition of Annex II to the 1947 Chicago Convention, the aircraft means any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth’s surface.⁴ And the definition of “aircraft” in Annex II is more abstract than the definition of “vessels” in 2005 COLREGS. The Chapter 3, General Rules of Annex II, enumerated several types of aircraft, such as power-driven heavier-than-air aircraft, airships, gliders balloons.

Sum up the analysis above, the institution of the rules of preventing collisions in outer space shall focus on the part of preventing collisions in outer space, including rules of preventing collisions during navigation in outer space and rules of preventing collisions during travel on the surface of the other celestial bodies. Now, the institution of former is more important than later. The following note only concerned about the institution of former.

2.2 The Basic Rules of Preventing Collisions

Although there are many different operating procedures and regulation of operating various types of vehicles, operators are required to follow some fundamental rules. The following will list some of the basic rules applicable to navigation in outer space.

2.2.1 The Rules of Maintain Look-Out and Visibility

Despite using the term “Look-out” and “Visibility,” This rule is not only including the visual measures to observe potential collision, but also including using technological measures. For example, the primary radar system and secondary radar system.

In rules of water navigation, according to the Rule 5 of 2005 COLREGS, every vessel shall always maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions to make a full appraisal of the situation and the risk of collision.⁵ This is the rule imposes obligations on the operator to take the initiative measure to preventing collisions by maintaining a proper look-out.

Although the rules of air navigation did not provide the same provision, Item 3.2.1 of Annex II to the 1947 Chicago Convention imposes similar obligations on the captain,⁶ and use an abstract item “vigilance to detect

⁴ The Chapter 1, definition Annex II to the 1947 Chicago Convention, Tenth Edition, 2005.

⁵ Rule 5, 2005 COLREGS.

⁶ The 1956 Grand Canyon mid-air collision revealed it is difficult for the pilot to see the other aircraft that are approaching with normal speed. And the Überlingen

potential collisions.” Because of the high speed of the airplane, it is hard to observe potential collision visually.⁷ Modern passenger aircraft equipped with ACAS and other instruments to detect the potential collisions. The purpose of Item 3.2.1 of Annex II is to emphasize the importance of pilot’s initiative measure of observing the potential collision, even with the help of Airborne collision avoidance system (ACAS) and air traffic management.

Another important rule of maintaining look-out and visibility is maintaining the visibility of the vehicle. In rules of water navigation, according to the Rule 20 of 2005 COLREGS, vessels shall observe the rules of using lights and shapes, no matter what the weather conditions should follow the rules.⁸ The Rule 22 of 2005 COLREGS set the specific standards for the lights to list all kinds of minimum visible ranges of lights.⁹ The Rule 24, Rule 25, Rule 26, Rule 27, Rule 29 specify vessels in particular conditions shall use proper lights and shapes to prompt other vessels about the potential collision.¹⁰

The Item 3.2.3 of Annex II to the 1947 Chicago Convention also provides the obligation of the pilot to display proper lights to prompt other aircraft. Including anti-collision light and navigation lights from sunset to sunrise or during any other period which may be prescribed by the appropriate authority.¹¹

Besides, ACAS, as a radio equipment for preventing collisions, has characteristics which are consistent with the Rules of Maintain Look-Out and Visibility. ACAS equipment is based on the secondary surveillance radar system, using the transponder to transmitting signals containing flight information of the aircraft, including height, speed, heading.¹² This process could be considered as maintaining visibility by radio. In the same time, the transponder is also receiving signals from other aircraft. After comparing the flight information of the aircraft itself with the flight information of other aircraft, the ACAS could predict whether there is a potential collision. This process could be considered as maintaining look-out by radio.

2.2.2 The Rule of Maintaining a Safe Distance and at a Safe Rate

The rule of maintaining a safe distance and at a safe rate was designed to preventing a potential collision, and the rule of preventing collision was designed to preventing collisions at time of collision risks have emerged.

mid-air collision revealed It is difficult for the pilot to determine the course and position of the other aircraft even with the help with ACAS equipment.

7 Item 3.2.1, Annex II to the 1947 Chicago Convention.

8 Rule 20, 2005 COLREGS

9 Rule 24, Rule 25, Rule 26, Rule 27, Rule 29, 2005 COLREGS

10 Item 3.2.3, Annex II to the 1947 Chicago Convention.

11 Item 3.2.3, Annex II to the 1947 Chicago Convention

12 the Chapter 1, definition Annex II to the 1947 Chicago Convention, Tenth Edition, 2005.

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In rules of water navigation, according to the Rule 8 of 2005 COLREGS, Action taken to avoid collision with another vessel shall be such as to result in passing at a safe distance.¹³ This provision describes the safe distance is a standard to determine whether the avoid actions are reasonable. When it comes to the vessels in the inland navigation, it should also comply with the provisions of the safe distance. Such as Rule VI and Rule VIII of Inland Navigation Rules of the United States¹⁴; the Article 13 of Rules for Preventing Collisions between Vessels on Inland Water of People's Republic of China¹⁵. In rules of air navigation, The Annex II to the 1947 Chicago Convention, also provide the safe distance in air traffic management, that an aircraft shall not be operated in such proximity to other aircraft as to create a collision hazard.¹⁶ It is another point of view to explain the safety distance: The safe distance is the minimum distance to prevent the risk of collision. At present, all United Nations Member States are parties to the Chicago Convention, the provisions of Annex II of the 1947 Chicago Convention have been translated into national legislation by 1947 Chicago Convention states parties. For example, The Article 91.111 of FAR-91¹⁷ and the paragraph (a) of the Article 91.111 of CAAR-91-R2,¹⁸ Both provided that no person shall drive an aircraft in close proximity to other aircraft and may have a risk of collision. In rules of road traffic, the paragraph 5 of article 13 of Convention on Road Traffic, 1968, provided that the driver of a vehicle moving behind another vehicle shall keep at a sufficient distance from that other vehicle to avoid a collision if the vehicle in front should suddenly slow down or stop.¹⁹ This provision also states that the obligation to maintain a safe distance is on the visible side. Although China and the United States are not parties to the Convention on Road Traffic, the two countries also provide for safe distance provisions in their road traffic rules. For instance, the article 43 of Law of The People's Republic of China on Road Traffic Safety.²⁰ In summary, maintaining a safe distance and at a safe rate is a universal rule of preventing collisions, operating spacecraft in outer space also need to follow this rule. Operators shall operate spacecraft maintain a safe distance to other spacecraft and ensure the speed of the spacecraft is controllable.

13 Rule 8, the 1972 COLREGS.

14 33 CFR§83.06, Safe speed (Rule 6) and 33 CFR§83.08, Action to avoid collision (Rule 8). In the United States, the Rules for Preventing Collisions between Vessels on Inland Water is the addition of rules applicable to the inland navigation to the 1972 COLREGS.

15 Article 13, Rules for Preventing Collisions between Vessels on Inland Water of People's Republic of China.

16 Item 3.2.1, the Annex II to the Chicago Convention.

17 14 CFR§91.111, Operating near other aircraft.

18 Article 91.111, the CAAR-91-R2.

19 Article 13, the 1968 Convention on Road Traffic.

20 Article 43, Law of The People's Republic of China on Road Traffic Safety.

2.2.3 The Rule of Right-of-way

The purpose of the rule of Right-of-way is the allocation of the obligations of preventing collisions. It means while two or more vehicles facing a potential collision, which vehicle should take measures to preventing collisions, also known as keep out of the way or give way. This rule is widely applicable to many modes of transport, like water navigation and air navigation.

In rules of water navigation, according to the Rule 18 of the 2005 COLREGS, usually, during in navigation on the sea, the higher maneuverability means greater ability to prevent collision. Therefore, the vessels which have greater maneuverability should keep out of the way of the vessels that have less mobility.²¹ This provision describes the vessels which have higher maneuverability should bear more obligation of preventing collisions. During in navigation on the sea, the higher maneuverability means the higher ability to prevent collision. This provision can also be embodied in the rules of inland navigation in many states. Such as Rule 18 of Inland Navigation Rules of the United States;²² The Rule 21 and Rule 22 of Rules for Preventing Collisions between Vessels on Inland Water of People's Republic of China.²³

In rules of air navigation, The Annex II to the Convention on International Civil aviation, also provide the obligation of preventing collision in air traffic management, that When two aircraft are converging at approximately the same level, the aircraft that has the other on its right shall give way, however, if the ability of preventing collision of these two aircraft is different, the aircraft with higher ability of preventing collision shall give way.²⁴ It is a similar point of view of the obligation of preventing collisions. Besides, this provision also reflects the maneuverability is not the same as the ability to

21 Rule 18, the 1972 COLREGS. Paragraph (a) of Rule 18 of the 1972 COLREGS provided that "A power-driven vessel underway shall keep out of the way of a vessel not under command, a vessel restricted in her ability to manoeuvre, a vessel engaged in fishing, a sailing vessel." The paragraph (b) of Rule 18 provided that "A sailing vessel underway shall keep out of the way of a vessel not under command, a vessel restricted in her ability to manoeuvre, a vessel engaged in fishing." The paragraph (c) provided that "A vessel engaged in fishing underway shall keep out of the way of a vessel not under command, a vessel restricted in her ability to manoeuvre." The maneuverability of these vessels, as specified in this rule, is gradually declining.

22 33 CFR§83.18, Responsibilities between vessels (Rule 18).

23 Rule 21 and Rule 22, Rules for Preventing Collisions between Vessels on Inland Water of People 's Republic of China. The Rule 21 provided that the manpower vessels and sailing vessels shall keep out of the way of the power-driven vessels. Because, during in the inland navigation, the smaller hull means the higher ability to prevent collision.

24 Item 3.2.2.3, the Annex II to the 1947 Chicago Convention, the exception in this clause is "power-driven heavier-than-air aircraft shall give way to airships, gliders, and balloons; airships shall give way to gliders and balloons; gliders shall give way to balloons; power-driven aircraft shall give way to aircraft which are seen to be towing other aircraft or objects."

preventing collisions. The maneuverability of a glider is usually higher than that of an airship. However, a glider may lose speed and altitude by taking actions to preventing collisions, it may cause a potential risk for the glider. Thus, the airships shall give way to gliders. This provision shows that the purpose of the allocation of the obligations is to maximize traffic safety. At present, the provisions of the obligation of preventing collision have been translated into national legislation by most states parties. For example, The Article 91.113 of FAR-91²⁵ And of the Article 91.113 of CAAR-91-R2,²⁶ Both provided that no person shall drive an aircraft in proximity to other aircraft and may have a risk of collision.

In summary, the Rule of Right-of-way is a common rule of preventing collisions, operating spacecraft in outer space also need to follow this rule. Operators shall determine whether the spacecraft shall give way to other spacecraft by the positional relationship between the spacecraft with other spacecraft, and take proper measures to preventing collisions.

3. Spacecraft Could Apply the Rules of Preventing Collisions in Air Navigation

As mentioned here above, some civil aerospace activities may involve operating a spacecraft navigating in the airspace of different states. And as discussed above, the rules of preventing collisions are determined by the zone where the vehicles are operating. In this context, it seems easy to determine which rules of preventing collisions shall be applied during those spacecraft's operating: During the stage of navigating in airspace, the rules of preventing collisions in air navigation shall be applied, and during the stage of navigating in outer space, the rules of preventing collisions in outer space shall be applied. The establishment of this institutional arrangement also needs to clarify the following two issues.

3.1. The Popular Commercial Spacecraft Could Apply the Rules of Preventing Collisions in Air Navigation

Firstly, the spacecraft which could apply to the rules of preventing collisions in air navigation should have the main features of the aircraft. According to the Chapter 1. Definition of Annex II to the 1947 Chicago Convention, the aircraft means any machine that can derive support in the atmosphere from the reactions of the air other than the reactions of the air against the earth's surface.²⁷ and the Item 3.2.3 of Annex II to the 1947 Chicago Convention list

25 14 CFR §91.113, Right-of-way rules: Except water operations.

26 Article 91.113, CAAR-91-R2.

27 The Chapter 1, definition of Annex II to the 1947 Chicago Convention, Tenth Edition, 2005.

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some typical aircraft, including power-driven heavier-than-air aircraft, airship, gilder, and balloon.

Therefore, all non-recyclable spacecraft excluded from the scope of application the rules of preventing collisions in air navigation, including the traditionally manned spaceships such as Soyuz and Shenzhou for its return to the atmosphere is free movement, or landing with parachutes.

The space shuttle is a model for commercial aerospace entities to design spacecraft, and the navigation of the space shuttle after returning to the atmosphere is similar to that of a glider. For example, SpaceShipTwo, the spaceplane of Virgin Galactic, fly on into the upper atmosphere powered by its rocket engine, then glides back to Earth and performs a conventional runway landing.²⁸ Thus, during this type of spacecraft navigating in the air, the rules of preventing collisions in air navigation can be applied.

3.2. The Application of The Rules of Preventing Collisions in Air Navigation Will Not Increase the Burden of The Pilot

Because of institutional arrangement mentioned above, the pilot shall follow the rules of preventing collisions of outer space when the spacecraft navigating in outer space and follow rules of preventing collisions of navigation in the air when the spacecraft navigating in the air. This institutional arrangement seems to increase the burden of the pilot. However, this worry seems to be misplaced. The result is illustrated by the example of seaplane.

As stated above, when a seaplane is navigating in water, it follows the rules of water navigation, such as the 2005 COLREGS, and when this seaplane navigating in the air, it follows the rules of air navigation. Item 3.2.6 of Annex II to the 1947 Chicago Convention provided the specially rules of preventing collisions for seaplane pilot.²⁹

However, those specially rules of preventing collisions are similar to the 2005 COLREGS and the Annex II to the 1947 Chicago Convention. For instance, the Item 3.2.6.1.1 Annex II to the 1947 Chicago Convention provided that “Approaching head-on. An aircraft approaching another aircraft or a vessel head-on, or approximately so, shall alter its heading to the right to keep well clear.”³⁰ The Item 3.2.2.2 Annex II to the 1947 Chicago Convention provided that “Approaching head-on. When two aircraft are approaching head-on or approximately so and there is danger of collision, each shall alter its heading to the right.”³¹ And the rule 14 of the 2005 COLREGS provided that “When two power-driven vessels are meeting on reciprocal or nearly

28 Slego, J., & Kraus, I. (2012). Return trajectory of the SpaceShipTwo spacecraft? numerical solution. Physics Education, 47(3), 309-312.

29 Note, Item 3.2.6, Annex II to the 1947 Chicago

30 Item 3.2.6.1.1, Annex II to the 1947 Chicago Convention

31 Item 3.2.2.2, Annex II to the 1947 Chicago Convention

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reciprocal courses so as to involve risk of collision each shall alter her course to starboard so that each shall pass on the port side of the other.”³² The above three rules provided same measures of preventing collisions when an aircraft or vessel facing an approaching head-on, that is changing the course to the right. In other words, when a seaplane facing an approaching head-on, regardless of where the seaplane is operating, and regardless of whether the seaplane is likely to meet aircraft or vessels, the pilot only need to change the course to the right to meet obligations of preventing collisions.

In summary, as long as the rules of preventing collisions in outer space in accordance with the basic rules of preventing collisions, the pilot will not be confused by two rules of preventing collisions.

Conclusions

Due to the existence of many common principles in air law and law of the sea. It seems to be easy to draw up the “Safety Rules” of the legal system of “Civil aerospace activities.” However, the biggest challenge in drafting the “Safety Rules” is how to define aviation activities and aerospace activities. This problem involves a controversial issue: How to define the airspace of sovereign States and outer space? Besides, How to drafting the procedure rules of space traffic services unit make a transition with air traffic services is also a challenge posed to the world.

32 Paragraph (a), Rule 14, 2005 COLREGS.