

Consideration of Commercial Orbital Facilities from the Viewpoint of Color Psychology

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Commercial space facilities needs more than safety and reliability to realize comfort and habitability. Color could be one of the key elements to realize this necessary comfort and habitability. Color effects both our perceptions and emotions, which are related to our psychological behavior. Also color effects our physical condition and physiology functions such as appetite and blood pressure. It is one of the ways to make affordable and effective improvements in comfort by making the best use of color power for both psychological and physiological aspects of living in space. This will contribute to habitability and work performance, maintain body conditions, control emotions, decreasing stress and tiredness and increasing overall comfort and enjoyment of life in the space environment.

I. DAWN OF COMMERCIAL HUMAN SPACE ACTIVITIES

It is the 10th anniversary of the dawn of commercial human space flight since 2001 when Dennis Tito flew to space as the first commercial customer in the world. And now is the time that US space policy has been drastically changed to become open for commercial companies to develop human space vehicles after the Space Shuttle will be retired in 2011. This change was begun with COTS started in 2005; and CRS, CCDev1, and CCDev2 are following. Now NASA is acting as a customer to buy commercial cargo flight services and crew flight purchases as well in the near future. Also, orbital commercial space facilities including space hotels have developed targeting commercial operation in 2015, as shown in Figure 1. While suborbital space vehicle development is entering the test flight stages. Virgin Galactic has started test flights in 2010 and other companies are also making big efforts for completing each test toward human flight tests stages to get into the market within a few years. Commercial spaceport development has been active all over the world to bring space business by suborbital space vehicle and to focus on the next generation Point-to-Point space flight.



Figure 1. Bigelow Commercial Space Facility and Boeing CST-100 ©Boeing

II. ELEMENTS FOR COMMERCIAL ORBITAL FACILITIES

Commercial Orbital Facilities including Space Hotels will be operating in the near future after many years of R&D. These are regarded as long duration facilities for living in space just the same as the International Space Station (ISS). However, what are the differences between Commercial Orbital Facilities and government ones except funding aspects? The elements of comfort, amenity, healing, fun, privacy and style will be more important for commercial orbital facilities as well as basic safety and reliability. People living in the space infrastructure – even for short stays - should be satisfied both physically and mentally, especially in the case of commercial activity for paying customers. Also, the longer time duration that people are in space, the more important it is that they reduce stresses and refresh themselves.

Furthermore, talking about commercial space activities such as space tourism, there will need to be new experience elements such as happy, exciting, interesting, premium, exhilarate as well as service and hospitality. It is a fundamental commercial aspect for paying passengers to be in a good condition even in space, to be satisfied with their stay in space, to have full immersion in the Overview Effect and enjoyable experiences in microgravity as much as possible. New design and engineering solutions are required to produce these commercial elements, too.

Meanwhile, there are several life functional categories, which are *eat, work, sleep, wear, hygiene, fun*, in our lives. Also, there are new elements required for long duration spaceflight such as *keep health and sanitary, privacy* and so on. For space tourism, *service* and *hospitality* are new functional elements, too. To date, the tourist customer visits to ISS have provided amenities more similar to a camping trip or expedition rather than anything approaching the level of luxury and amenities that a multi-million dollar price tag would suggest. So far this has been acceptable because there is only a single orbital spaceflight provider and every available seat has been sold. However, over time the normal competitive market forces in any high-end experience offering will begin to migrate into the space environment, and quality of life (QOL) will become a market factor.

III. HABITABILITY FOR COMMERCIAL ORBITAL FACILITIES

The current state of the art in habitation on the ISS can be described – at best – as minimal or spartan, more akin to a camping trip in a recreational vehicle or an expedition than a true long-term habitation environment with elements of comfort and style. Government astronauts will of course not complain about these conditions because it is their job to be in space and working, regardless of how comfortable or uncomfortable the living environment may be. The first eight commercial orbital spaceflight participants who have visited the ISS for a week or so have not complained too much about the minimal living conditions. However, it is now the time to consider commercial facilities through habitability criteria. It is an essential element in the growth of orbital commerce to develop a new design philosophy that will enhance QOL in space.

There are varieties of elements such as design, materials, light effects, noise, air condition, temperature, humidity and so on for habitability in space. Color is one of the elements which effects habitability in space directly.

IV. COLOR AND COLOR PSYCHOLOGY

Color is filled in our lives no matter how people regard it consciously or unconsciously. Everything on earth has color and color makes everything characterized. We can recognize easily that color exists in everywhere such as nature, culture, history, religion, ethnic, nations and so on. And in the industrial field, we make the best use of color, for example, for marketing, what is called color marketing, communication, so called color language.

Color has two aspects of functions, one is information transmission function and the other is to stimulate emotion. As for the information transmission function, there are color marking patterns such as subway map and cable differences, showing status and situation such as fruit ripeness and peoples condition from face color, sign and language such as road sign and so on. As for the other aspect of stimulating emotion, it makes our life. There are image showing such as Corporate Identity color and products' packages, showing beautiful such as cosmetic, effect to our mind such as beautiful costume and cool interior. In our circumstances, color has three functions of classify, transmission and emotion.

People use color to express their mind like language unconsciously in their daily life. In this meaning, color is a language to express senses and emotions. Color psychology is the relationship of color and human being. Color has peculiar emotion in common and private emotion by our own histories and gender. Psychological power of color works both toward cognition and emotion. Effect of color toward cognition is such as cool and warm color, heavy and light color, distinguish and non-distinguish color and so on. While effect of color toward emotion is that warm color make us high temperature when we are depressed and cold color makes us calm when we are impatient⁽⁷⁾. And color also provides us with physiological effect more than psychological one as well as other animals⁽¹⁾. This is because the autonomic nerve which controls all organs' works has strong affection by color. Red increases of tension of parasympathetic nervous system of autonomic nerve while blue increases of tension of sympathetic nerve of autonomic nerve and cools down high temperature and reduce active hormone. These matters show that effect of color for motion relates not only psychological but physiological aspect of human beings.

Color from the psychological aspect has been studied for many years. Johann Wolfgang von Goethe mentioned color and psychological sense in his book of Theory of Color which was published in 1810 and he systematized color from the aspect of psychology for the first time. After 1900, many scientists studied the relationship between color and mind.

Because all colors in our life have healing power, we can reduce tiredness and stress, and increase happiness and recover good relationship with others by using the best use of colors. Using color in our daily life is just chose color for your daily things such as cloth, food, and interior. Everyone has experience of changing mood by changing color of clothes. However, this is not only changing mood but changing condition physiologically such as blood pressure, muscle function being well as well as brain, organ, pulse, and blink rate. Color is also important for our health and well-being, as well as food and air.

There are two reasons that color is useful for our human body⁽⁵⁾. The first reason is that color, the continuous vibration of light, and cell, the continuous vibration of human body, are vibrating effectively each another. Color is each wave which vibrates with certain cycle, for different color means different cycle of vibration. While the human body consists of elements such as hydrogen and carbon as well as any other matters and these elements always vibrate. In this reason, it could be considered elements of our bodies tend to be effect vibration of light. We have bad condition without natural vibration rhythm. Healing by using color is one of the ways using light to make up original condition to use the difference of waves of vibration among colors. The color which makes you feel good is the color your body seeks for at that moment for vibration between cell of body and light of colors. This is the reason that we can manipulate our condition by using particular colors for particular situations.

The second reason that color is useful for your health is that we have brain which has function that information from color for body control⁽⁶⁾. Color from our eyes as wave of light is changed to electric signal on the way. Then it is transmitted to nerve as fluent electric current. After that, color information reaches the high function of the autonomic nerves in brain. Different colors have different patterns of signal to the autonomic nerve and effect the production of kinds of hormones and its amount. Also, depending of the color, we have different reaction of body and mind because hormones cause emotion, immunity, and behavior. And depending on colors, the language nerve is stimulated and it brings out old memories very clearly. This kind of thing influences our emotional behavior, using color is stimulating a part of the brain and helping control it.

Color is deeply related to body condition, and we need a certain color in the certain condition. Each color has a power to recover from different bad condition such as red color inviting appetite and increase blood pressure and making us active. Blue and vague color can heal us from tiredness, especially short wave color like blue and violet effect parasympathetic nervous system easily. Dark colors such as navy, brown, black, charcoal gray reduce heavy tiredness and stress. Too bright colors makes us tired because too much stimulation of light. Hue, brightness, saturation are all deeply related to healing⁽¹¹⁾.

V. ROLE OF COLOR FOR SPACE FACILITIES

Color has practical roles for space habitats generally, which are (1) to distinguish (2) to communicate (3) to mark out or not (4) to order (5) to make space clear (6) to show elements (7) to tell us area (8) to make functions easy (9) to increase or decrease feeling of weight (10) to alarm and so on⁽¹⁰⁾. Also, color has feeling roles such as (1) to make it impressive (2) to make it characteristic (3) to adjust feeling (4) to adjust temperature (5) to speed up rate of work and so on. Roles of color for human space infrastructures, there are three roles of (1) to work psychological effects (2) to decrease dreary life and work in space (3) to prevent losing perception in space in addition to these practical and feeling roles. The general psychological and mental functions of color selection are shown in Figure 2. Perhaps most important, color choices for any space habitat are a ZERO cost item in a very high value built environment.

Color Magic	
	White: active and bright feeling
	Green: relax and stable in behavior
	Blue: reducing tiredness and stable spirit
	Dull colors: reducing tiredness
	Brown: stable feeling and sober behavior
	Gray: stable feeling and stable mood
	Purple: healing from tiredness
	Pink: calm and bright feeling
	Red: increasing appetite and vitality, active feeling
	Yellow: bright mind
	Black: Reducing high tension and stable activities

Figure 2. Effects of Color Choices⁽²⁾

VI. COLOR PSYCHOLOGY FOR HABITABILITY IN SPACE

The more commercial and the longer the stay in space, the more important that color coordination becomes for the interior of human space infrastructure. Using the power of color will directly contribute to enrich mental health aspects in space. Color effects both our perception and emotion which are related to our behavior psychologically such as encouraging our enthusiasm, giving us healing, and reset for fresh mind. Also color affects our physical condition and physiology functions such as appetite and blood pressure. It is one of the ways to make improved comfort by the best use of color power both psychological and physiological aspects for living. This will improve work performance, maintain body conditions, control emotions, decrease stress and tiredness and increase overall comfort and enjoyment of space. Figures 3 and 4 below show the physical and health effects of various color choices.

Color in a closed space habitat has relationships with lighting, fabric and other materials and textures of space interior design. Also, the color of clothing is one of the big parts in space life and it can be changed easily. Color of food and drink are also directly connecting with our bodies, too. Thus, color power can be effective for living in space in any item such as wear, food and drink, interior design, and so on.

Color and Physiological Phenomenon

	Red: increase blood pressure and pulse
	Red & Yellow: increase appetite
	Yellow: tense for eyes
	Yellow green & Green: normalized physical functions
	Blue green & Blue & Blue violet: reducing blood pressure and pulse

Figure 3. Physiological Color Effects⁽²⁾

Color and Health Condition

	Red: frustration, active, vitality, self-insistence
	Blue: tired, refreshment, rest, calm
	Yellow: lonely, bright, fear
	Green: lack of sleep, tendency of anemia, tired physically
	Black: destruct, anxiety, nervous for noise, avoid strong stimulus
	White: follow ship, exercise, good balance
	Gray: Nervous, good condition for work and judgment
	Purple: Sickness and after ill, depression, non-active
	Pink: good condition physically, sentimental, consolation
	Brown: calm, no exercise feeling

Figure 4. Health Effects of Color Choice⁽²⁾

VII. COLORS FOR LONG DURATION LIVING IN SPACE

Regarding the colors for commercial orbital facilities including space hotel and long duration living in space, it is expected that certain colors are lacking and certain colors are excess. For example, having unbalanced foods and fixation on a certain color makes our body unbalanced. In this case, opposite color can make these imbalances reduced and recover a good balance, which is called allopathy. Also, when we have the only one wavelength continuously, we lose balance and have harmful influence from color. There are records that astronauts were eager to have something green. The colors which are lacking in space could be red, orange, yellow, and green, especially, browns of earth color and greens are the color which people can recall nature on earth. Galactic Suite, the Barcelona based space hotel company, uses Toscana Green for the primary interior color of their space hotel, shown in Figures 5 and 6.



Figure 5. Galactic Suite Space Hotel ©Galactic Suite

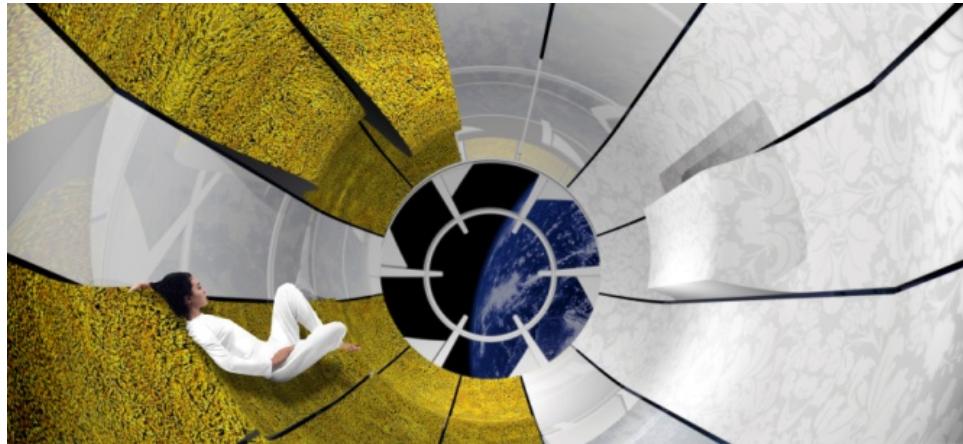


Figure 6. Interior of Space Hotel ©Galactic Suite

VIII. COLORS FOR SHORT DURATION IN SPACE

Regarding the short stays in space such as suborbital space flight, color is still important to design the cabin for suborbital space vehicles so as not to disturb the impressive and emotional space flight. Therefore, it is necessary that the cabin interior should not be a stimulating design. Psychological complementary colors could be good to use for looking out the beautiful window view. The psychological complementary color is the spectrum phenomenon which is the phenomenon that has opposite color on retinas to reduce the color's stimulus when we see a color. Therefore, when we see the color for a while, the color fades because of psychological complementary color appearing. If the main color of earth is blue, its psychological complementary color is from yellow to orange. By making the best use of the way, we have beautiful window views of earth in the cabin which interior color is from yellow to orange effectively. From yellow to orange for accent color or pastel yellow to pastel orange to reduce saturation could be used for the cabin interior to make it lively feeling. Furthermore, the combination between colors and lighting is the most effective way to create suitable interior spaces for dramatic space tourism flight.

For example, Spaceship2, a suborbital space vehicle which Virgin Galactic has been developed as shown in Figures 7, red is used for accent color for a part of space suits and seat belts in cabin in addition to pale blue base color. Also, cabin lights contribute for dramatic space flight. The interior is designed by Richard Smith as well as the spacesuits. The EADS Astrium spaceplane, shown in Figure 8, uses yellow and gray for cabin of suborbital vehicle as accent colors in addition to pale ivory base color. The design was performed Mr. Mark Newson, one of the outstanding industrial designers. He designed it to have safety issues first. Then, he designed other functions for passengers to have fun time during the space flight such as big windows for viewing earth.

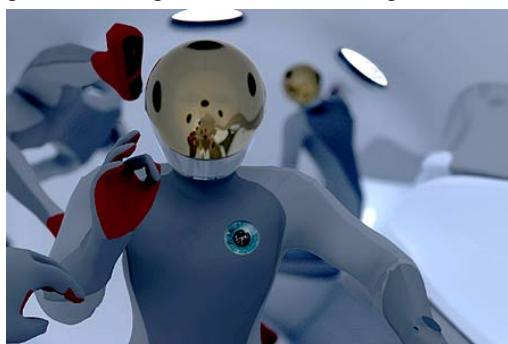


Figure 7. SpaceShip2 Cabin ©Virgin Galactic

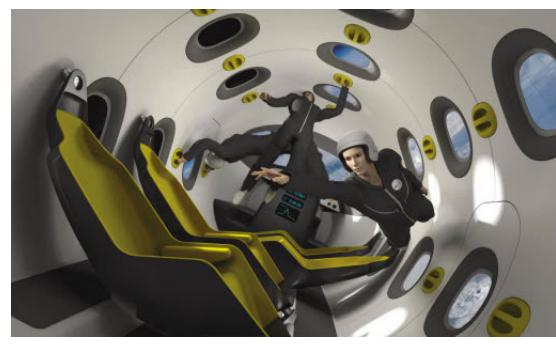


Figure 8. The Cabin of EADS Astrium suborbital vehicle ©EADS Astrium

IX. QUALITY OF LIFE IN SPACE

JAXA established the “Kibo utilization forum” to create new projects which will form new value in society by using the network with a variety of people’s ideas, experiences, and engineering beyond each organizational framework. There are thirteen study groups as follows:

- (1) Research group regarding sense of interior space in the ISS
- (2) Workshop on sleep in outer space
- (3) Advanced toilet in space
- (4) Kyoto’s traditional culture in space
- (5) Functional space food
- (6) Colloidal material research group -light designed with microspheres-
- (7) Toilet design improvement for astronauts and serious challenged
- (8) Space life comfort enhancement
-Seeking quality of life between space and earth-
- (9) Physiology information monitoring –both sleeping and awake-
- (10) Human and society in space
- (11) Society for acupuncture science in space
- (12) Space cooking
- (13) New space media utilization

Space life comfort enhancement research project-Seeking quality of life between space and earth –has been started with JAXA which will enrich living in space using additional commercial elements such as color power and fashion. This research project will consider new ideas for products and services to enrich and make comfort living in space, which will improve habitability in space as well. Also, these will be used in our ordinary life on Earth as commercial items with strong “space standards”. Products and services from living in space can drive space commercialization and contribute to our lives and economic development both in space and on earth.

Space QOL is expected to broaden markets on earth. Engineering, products and services for QOL in space must be innovative and high quality because of the high technology level required to reliably operation in space. These products and technologies must be useful on earth, too. Also, living in space itself doesn’t have so broad a market so that the markets on earth are necessary, inevitable, and crucial. These kinds of things have been done as spin out and spin in of space technology around the world for many years. Therefore it is natural to perform spin out and spin in of engineering, products and services for QOL between in space and on earth.

Meanwhile, the high cost of launching supplies and logistics require that living in space must have an extremely eco lifestyle with lots of eco-engineering and green technologies. Therefore, we can realize eco aspects in our daily life on earth using space technologies and ways of thinking and operating in space.

X. CONCLUSION

For long duration living in space and commercial activities in space, elements such as comfort, fun and favorite will be necessary in addition to safety and reliability to improve habitability and quality of space life. To realize this, to use colors is effective and one of key elements to improve habitability and quality of life in space. We depend on our five senses of sight, hearing, smell, taste and feeling to get information to live and depend on sight more than eighty percent. Because color effects our perceptions, emotions, physical condition and physiology functions, it is one of the ways to make improve comfort by making the best use of color power to improve both psychological and physiological aspects of living in space. I expect that this will improve habitability so that work performance, maintenance of body conditions, control of emotions, decrease in stress and tiredness and increase in overall comfort and enjoyment of life in the space environment, though it has not been measured in space yet.

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