FUNDAMENTAL PRINCIPLE OF HIGH RELIABILITY OF THE MANNED FLIGHT TO MARS, AND EVOLUTIONARY CONCEPT OF THE EXPEDITION TO MARS

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ABSTRACT

This paper is consisted of two parts.

The first part is devoted to the Squadron Concept, which is the Fundamental Way to achieve high reliability for the Manned Flight to Mars. The Squadron (in the context of this article) is a group which consists of several manned spaceship, which all are equipped with means of interaction and mutual assistance and devices for moving a crew from one spaceship to another. This concept has universal significance for any manned flight beyond the Earth gravitation field, because this scheme rejects fatality of an accident onboard Squadron's spaceship.

The second part content is a sketch of The Evolutionary Concept of the Mars mission. Justification presented of opportunities significant power electric propulsion reduction for Manned Flight to Mars.

The Squadron Concept of Manned flight to Mars

Introduction

Manned Mission towards Mars is one of the fundamental tasks of contemporary cosmonautics. It stands in the sequence such steps in Outer Space exploration as: the first human space flight, creation of Space Stations, Manned Missions toward Moon, exploration of Moon, investigation and exploitation of the Solar system planets' resources.

Manned Mission towards Mars is an important step of the human civilization evolution.

Research and design activities to determine shape, structure and technology for realization of Manned Mars Mission, were begun in USA and USSR in early 1960's, right after the First Earth Satellite launch [1].[2] Before that, at 1948-1952, taken captive in USA, Wernher von Braun started his works devoted to the Human flight to Mars. [3]

In USSR, a primary complete comprehensive concept of the Manned Mars Mission was worked out during 1961-1969. General Constructor Sergey P. Korolev at the RSC "Energia" (OKB-1 then) initiated this activity and it was later continued in works of his colleagues and successors, including numerous co-operating collectives [4].

This primary detailed project was created on a "single manned ship" concept. According to this plan, only one a single manned spaceship should transport a crew and all systems required for full realization of the Mission toward Mars. The expedition was planned as a short one with duration of staying on Mars surface for 30 days.

By the late 1960's, Von Braun had chosen nuclear thermal rocket powered expeditions. He had refused from the 1946-1952 concept of "many manned vessel" expedition and had chosen a concept of expedition with a single manned ship [5]

All other known studies have in mind a transport of the crew towards Mars and back to the Earth using only one manned spaceship.[6],

Opt for the use of a single manned spaceship is based on a probabilistic logic. Let the vehicle reliability is equal to $\mathbf{r}$, $\mathbf{r < 1}$. If the number of ships (in any Group) is $\mathbf{n}$, the probability that the emergency would not happen on any group's vehicle is expressed by the formula:

$$\mathbf{p\ (n) = r^n} \qquad (1)$$

$\mathbf{p(n)}$ **-** probability of accident-free flight. It decreases proportionally to the $\mathbf{r^n}$.

It is essential that all ships in the Group are autonomous, and if emergency occurs in interplanetary space (it is essential), then it is fatal for the crew of the ship in emergency.

Example:
Let $\mathbf{r} = 0.9$, $\mathbf{q} = \mathbf{1\text{-}r} = 0.1$, $\mathbf{n} = 3$.
$\mathbf{q}$ is the probability of an accident for an one ship. Binomial formula for this case is:

$$\mathbf{(r+q)^3 = r^3+3r^2q+3rq^2+q^3} \qquad \mathbf{(2)}$$

$\mathbf{r^3}$=0.729 – it is probability of no accident case,
$\mathbf{3r^2q}$ =0.243 – it is probability one any ship may be in an accident,
$\mathbf{3rq^2}$=0.027 – it is probability that any two ship may be in an Accident
$\mathbf{q^3}$ = 0.001 – it is probability all ships are in accident.

So, we can see that the increase in the number of autonomous vehicles in the group flight increases the probability of crew loss. In this example, the increase in 2.7 times compared to option that uses one manned spaceship. Moreover, although the probability increases from 0.9 to 0.999 for some human to reach Mars, the result above is unacceptable for Martian expedition idea.

However, a single manned spacecraft, which flies outside the Earth's gravitational field, would be trapped by any incident fatally. This is unacceptable as well.

A Manned Mars Mission Squadron Concept. The definition of the Squadron.

The real alternative is given by the Squadron Concept, see fig.1.

"Squadron", in the context of this article, is a group of spaceship, compact moving in interplanetary space. The structure and equipment of Squadron’s ships gives, at an accident event, the ability to carry out “rescue operation” with participation of serviceable ships’ crews. The opportunity of mutual assistance for all the Squadron’s spaceship crews changes radically the estimation of the Squadron flight reliability.

Squadron composition and formation

Three Squadron alternative compositions were investigated for targets of this article. They do not cover all possible versions, but do permit to understand characteristics of the subject under investigation.

A Squadron consists of several spaceship (from two to four spaceship in a Squadron have been considered). If the number of spaceship **n**=2, then both spaceship are manned; at **n**>2 the number of manned spaceship, while launched from near-Earth orbit, remains equal two. Four or six crew members are spread between manned spaceship. Each spaceship expendable reserves should have amount sufficient for the complete crew.

Special note should be made: the increase in the number of spaceship in two, three, four times (2 ... 4 instead of 1) will not result in the same increase in the the mission cost. It follows from a well-known fact: to manufacture any spaceship for a specific space program we need 1/10…1/20 from the cost of technological and experimental finishing of a pilot sample, and even smaller part of the expenses for creation the program infrastructure. Hence, increase in quantity of manned spaceship will result in cost growth of mission's manned part by 10…20% and less, and if we take into consideration hardware and energetic components of the mission, cost excess will be yet less.

It is especially true *for the expedition Evolutionary Concept*, described in the second part of this article, because the expedition's spaceship is significantly simpler in this case.

The same considerations permit to admit, that each Squadron ship will be completely provided with systems and consumables quantitatively adopted for all expedition staff. By this mean the scope of the rescue operations and, consequently, time for their implementation is minimized (we will see below, that it is important), and consequently failure probability of the rescue operation is diminished.

Squadron is formed on the high near-Earth orbit (H=800…1000 km). Transport rockets deliver crews to space ships. For further flight, Squadron’s spaceship use electrical rocket engines with nuclear energy sources (The alternative version is … with solar-electric energy sources). Optimal distance between the ships (about 300 km) is customized on this start orbit. This distance permits to reduce radiation dose from nuclear reactors to the acceptable level (protective screen protects its “own” crew only). In other words, choice of such a distance allows not to change design principles for a shadowy screen protection from reactor radiation. On the other hand, this distance is small in comparison with interplanetary distances. It defines reasonable time needed for manned spaceship or onboard transportation vessels (on-board apparatus for individual transportation) to get closer and render aid to the spaceship in emergency. Squadron spaceship take a start from near-Earth orbit practically simultaneously.

Statistical Characteristics for the Mars Mission Squadron Concept

The target of this statistical calculation is to show, how the Squadron Concept increases success probability of an expedition.

It should be noted that failures of separate spaceship in Squadron are independent and it is used as a base of calculation. This is extraordinary important factor, especially being combined with possibility of mutual assistance of spaceship crews..

It is very hard to avoid mutual dependence of crashes no matter how much labor/funds is invested into design of a separate spaceship (in general meaning, in any rather complicated system). It is impossible to avoid mutual dependence of crashes within a spaceship. If we consider a manned flight, psychological dependence adds to, and, consequently, reliability does not increase in such technical system, as it gets more complicated. Reliability can even diminish, as the system gets more complicated – due to failure interactions and their superposition.

On the contrary, if independent failure principle is realized in case of several spaceship separated in space, then it is possible to increase reliability by investing additional fund. But, this sentence works in combination with the principle of mutual assistance only.

The game is worth the candle. One has to keep in mind that when reliability asymptotically gets closer to the value 1.0 (with its increment by only several percent) it results in decrease of failure probability in several times and/or in tens of times.

In reference to our subject, this statement is extremely important as it shows a direct way to increase success probability by way funds investment.

Equations describing task implementation probability

The following relation presents mission successful completion, P:

$$\mathbf{P = 1 - (q + q_1)} \qquad (3),$$

Where **q** – transport operation failure probability or critical emergency situation probability during the flight,

$\mathbf{q_1}$ – the same on all other stages (descent to Mars surface, stay on the surface, Mars take off, and landing on the Earth surface).

The variable "q" structure is considered further.

Let spaceship reliability is **r**, then the probability of an emergency situation (ES) is equal, accordingly, **1-r**. If a Squadron has **n** amount of ships, then relation (2) gives probability **F** that at least one emergency can happen:

$\mathbf{F = 1 - r^{n}}$ (4)

As it is seen from relation (2), if the quantity of ships in Squadron increases, then the probability of an emergency with at least one ship in the Squadron grows ($\mathbf{r < 1, r^{n} < r}$).

This effect from increasing of system's items quantity (it is discussed above) is compensated, and success probability rises in comparison with the "one-ship version" due to: a) failure independence in different ships, b) opportunity for mutual assistance and displacement of crew off the ship in emergency to those in a good working condition. A variable "s" appears then in calculations – probability for rescue operation successful execution.

Assuming success probability of the rescue operation **s=1**, statistical characteristics can be described by a full probability formula for binomial distribution. Let **q** be a failure probability at a Squadron's spaceship, **r** - a Squadron's spaceship reliability, **q**+**r**=1. In case of n spaceship:

$1 = \mathbf{(q + r)^{n}}$……………………………………………………………….. (5)

Formulas describing statistical characteristics for a Squadron for s=1 are given in Table 1. The result: if **s**=1, a Squadron flight will be successful if at least the one of Squadron's spaceship remains operational.

Table 2 gives formulas describing statistical characteristics for a Squadron under the condition that probability of a successful rescue operation **s**≤1.

A parameter E_n (E_2, E_3 and accordingly E_4) is considered as a criterion for Squadron formation effectiveness. This number (which is much higher than 1 in calculations presented) is a relation for a single-ship mission failure probability to the appropriate probability in case of Squadron flight.

$\mathbf{E_{n} = q/(1 - R(s)_{n})}$…………………………………………………..(6),

where $\mathbf{R(s)_n}$ – probability for a Squadron flight successful completion with "n" ships in the Squadron, and "s" -- rescue success probability.

Calculation results are presented in Table 3. Calculations are performed according formulas, given in Tables 1 and 2, for **s**=0.95 and **s**=0.98. These "**s**" magnitudes comply with reliability meanings for contemporary systems, which have been used for crew transportation to/from Orbital Stations since mid 70's (The reliability of aforesaid systems even closer to 1 really).

One can see that in case of Squadron flight with these "**s**" values a failure probability can be diminished in times and/or tens of times.

Fig. 2 shows dependence of the figure **E** (effectiveness) on "**s**", when "**s**" lies in 0< s ≤ 1 range. It is visibly that Squadron formation effectiveness is sensitive to "**s**" meaning and grows higher than 1.0 at **s** > 0.5. [7]

Manned Spaceship Structural Scheme

Mission's manned spaceship should be equipped with devices ensuring successful rescue operation. Apparently, a rescue apparatus will be included into the systems nomenclature of both manned and unmanned spaceship of the Squadron. The apparatus should be mounted on an appropriate docking unit. Besides, there should be provided a spare docking unit, on which, if necessary, a rescue apparatus with the crew could be docked to render support in emergency, or another rescue apparatus, originally based on a different spaceship, can be docked.

Availability of microwave or laser channel for distant energy transfer onboard Squadron spaceship can be rather an important additional resource.

Peculiarities of rescue operation.

It is written above, that failures are independent if a failure occurs with any spaceship of Squadron. It is really so, but since other Squadron spaceships are engaged in the rescue operation, this condition does not exist on this stage of operation. It is clear, if a failure happens at an active part of flight trajectory then Electric Rocket Engines of all spaceships should be switched off in order to a rescue operation could start and they shall be switched on after the operation is finished. This procedure disturbs the basic flight trajectory, and the next part of the flight has to be fulfilled in concordance with a corrected plan of the flight.

Thus a rescue operation consists of two steps.

The first step. Shutdown of all rocket engines of all ships is the first action, and then a technical problem will be overcome. Due to specific of an Electric Rocket Engine - do only very small variation of the trajectory parameters at each moment of time, scattering of a Squadron is thereby prevented.

The second stage. All Squadron ships, which are in service, continue flight. Electric Rocket Engines are switched on and the flight continues along a corrected trajectory, so as the prescribed trajectory has been perturbed, as result of electric rocket engines stopping.

Therefore, the parameter "**s**" must consist of two multipliers

$\mathbf{s}=\mathbf{s}_1*\mathbf{s}_2$.

Where s1 is probability to resolve a technical problem and s2 is probability to complete the flight along a corrected trajectory successfully.

A flight example along a corrected trajectory is given in fig. 3. This is a typical situation where the failure occurred during active phase of the flight.

Electric Rocket Engine's important quality manifests itself here. Electric Rocket Engine is the critical solution to prevent Squadron scatter in case if malfunction emerges on the active part of trajectory (in interplanetary space and on boundaries of the gravitational fields of the Sun and planets as well) and, after rescue, to complete the flight successfully. It is due two features of small thrust Electric Rocket Engine: small trajectory change within short period of working time and (it is important, too) its ability to vary specific impulse.

Note: Squadron Concept is incompatible with high-thrust rocket engines, i.e. chemical fuel rocket engines and nuclear thermal rocket engines, because these engines cannot prevent a Squadron scattering at a failure event.

Evolutionary Concept of Expedition to Mars

Squadron concept presented above is the important part of Evolutionary Concept of Mars mission, but it is only a part. The Evolutionary Concept of Mars expedition is presented below.

The expedition concept considered here means a first special scientific expedition, which is the first successive step in the chain: first complete cycle scientific expedition (=The Expedition) // Permanent Station on Mars surface // a Settlement on Mars. See fig. 4

The concept of The Expedition renounces such earlier ideas: expedition as a short visit on an unprepared place on Mars surface; an expedition realization by use one grandiose unique spaceship. These outdated ideas are presented comprehensively in the observe [8].

One can see there: this kind of the expedition fits within value range of electrical power of Electric Rocket Engines from 10000 kW up to 50000 kW. One must know figures which have been reached up today in reality: for nuclear power unit in Space – 5 kW, for solar batteries in Space – 120 kW. It is significantly below of above shown demands. It should be noted however that an Electric Rocket Engine of 500 kW power has been tested to date.**[9]**

Such contrast is between the maturity level of cosmonautic technology, which is practically ready for the Expedition to Mars, and technical level in space nuclear and solar energetics.

The Evolutionary Concept points the way to overcome this gap.

Main features of the concept are:

A) Expedition's Camp on the Mars surface is prepared for the Expedition accommodation in advance.

B) The whole equipment of the Expedition have to be distributed between several cargo spaceship and, as result, the economically comfortable distribution of whole expedition process along creation time is realized. Each functionally independent component of the Camp is delivered with use a separate special cargo spaceship.

C) The Squadron Mode is an integral part of the Evolutionary Model.

D) All participating spaceships on the stages of expedition infrastructure and the expedition staff delivery are equipped with Electric Rocket Engines.

Electric Rocket Engines power grow from one step to another during their use within the Project. Engines become more effective to be implement the task of the expedition staff delivery. All adequate equipment: spaceships and descent vehicles, and all equipment for the return flight have to be mastered in this time period, using unmanned format.

It is additive fundamental condition of Squadron Concept efficiency.

The sketch of The Evolutionary Concept

The sketch of Evolutionary Concept of Manned Mars Mission is given in fig. 5.
This sketch of Evolutionary Concept of The First Mars Expedition supposes that this program consists of four stages.
The first stage is arrangement of The Expedition's Camp on Mars surface.
The second stage is delivery and engineering of Residential facility on the Expedition's Camp territory.
The third stage is delivery of The Expedition's Crew to the Camp on Mars surface.
The fourth stage is to return the Crew back to the Earth after the Expedition completion.

Below we present a list of objects (and/or operations) that the transportation system delivers (fulfils) at each stage. Transportation system is considered equipped with Electric Rocket Engines with Nuclear Power Plants as sources of electric energy.

First stage

1. A cosmic pier on circummars orbit to moor spaceships equipped with Nuclear Power Plants. All transportation spaceships should moor to the pier after they had fulfilled their task. This is perhaps a useful idea to avoid nuclear pollution of Mars sky.
2. The Camp Nuclear Power Plant (CNPP) and components of the electric energy system shall be delivered and installed on The Camp territory. It will work as main source of electric energy for all equipment of The Expedition. [10
3. Technique for construction of CNPP shield from radiation with the use of Martian soil (excavator, bulldozer).

This technique will be used to create a wall around The CNPP to diminish radiation dose in the habitable zone of The Camp.

Afterward this technique will use Martian soil to create an asylum for The Crew's Residential Facility to defend The Crew against the CNPP radiation and against high energy Space Radiation.

4. A technique to move and to create the Residential Facility in The Camp.

Residential Facility will delivered on Mars surface without of the expedition's crew. It has to be transported after descending, and then have to be organized. and installed.

5. A robotic vehicle and human-like robots are delivered into The Expedition's Camp. Their task is to provide meeting of landing astronauts and to help astronauts to recover after arrival and transport them to the Residential Facility.

The second stage

6. Rockets and means for interplanetary backward flight. This equipment has to be fully tested during the Camp creation period. The Squadron designed for reverse flight is scheduled to arrive to Mars orbit before the moment when direct flight Squadron will deliver the crew of the Expedition.
7. The Residential Facility is delivered on the territory of the expedition's Camp. The Camp's equipment is being prepared to accomodate The Expedition's Crew.

The third stage - manned stage

8. The Squadron of manned spaceships delivers the expedition's crew to low Mars orbit. The crew of each manned spaceship is placed in the onboard residential module, which is provided with a radiation shield. Radiation shield is composed of two components: a heavy metal screen and a screen, which uses propellant tanks.

9. Astronauts land on Mars surface using of a personal landing vehicle. This solution has two advantages: it gives maximum probability the expedition will be performed and it gives the cosmonauts the opportunity to support each other.

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The fourth stage

10. The following procedures should be fulfilled to complete a return flight back to the Earth.

Each spaceship's residential module (of direct flight) docks by special electric rocket engine modules (for back flight), which have been previously delivered to a low Mars orbit. The Squadron for return flight is prepared by this way.

Delivered in advance Chemical Rockets will bring the crew on board of "Squadron's return flight spaceships" and then the return flight will be undertaken.

About Electric Rocket Engines power operating range in the Evolutionary Mode of Manned Mars Mission

It is obviously, that the Evolutionary Mode gives more moderate production and financing regime of this enterprise, similar as it realizes in ISS project within recent 16 years.

There is a very important additional component in this mode, and it was the main motivation to develop theory of the Expedition organization version. It is a diminishing of electrical power of Electric Rocket Engines participating in all delivery operations at all four stages. Power calculated values are equal to 125…300 kW for the first stage and and 900… 1100 kW for the second and subsequent stages.

Such power reduction is consequence of three factors:

1) 1) Expedition's whole cargo distribution between all delivery spaceships. As a result, the standard payload for cargo ship is 20 ton. Maximum mass - a mass of manned spaceship equipped with own radiation shield - 42 tons.

2) A significant increase of interplanetary flight time, in all cases, except for a manned flight case. This factor greatly affects the power level.

3) Decrease of specific impulse of electrical rocket engines. Relocation cargo delivery problems to existing heavy launch vehicles. Now optimization criterion is not the minimum value of total mass. Optimization objective is to decrease the price, among other by reducing the power of electric rockets, which have to be created.

Calculation results are presented in table 4.

Tool of this calculation was the analytical results which had presented in [11].

Summary

1. The concept of interplanetary manned flight in a Squadron spaceships mode, provided with technical means mutual assistance, consist of two theses:
First, crashes independence is realized for each Squadron ships.
Second, due to crews mutual aid possibility security of the crews and the expedition success probability increases significantly and, what is very important, possible accident fatal result eliminates.

2. Only Electric Rocket Engine has to be used in Squadron Concept Manned Interplanetary Flight. Squadron Concept is incompatible with high-thrust rocket engines, i.e. chemical fuel rocket engines and nuclear thermal rocket engines, because these engines cannot prevent a Squadron scattering at a failure event.

3. The Evolutionary Mode of Martian expedition is presented, which is concerted with the current state of the space-rocket technology and with a vision of real prospects of nuclear–electric or solar-electric rocket engines in combination with idea of radical fragmentation of Expedition payload.

4. It is a more realistic and much more reliable version of the Expedition, aimed to bring its implementation closer in time.
Nevertheless, for this target a quantitative breakthrough in spaceship energetic is needed.

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TABLES

Table 1

The formulas of the squadron structure statistical characteristics.
Rescue mission success probability s = 1

Squadron ships number, **n**	Full probability formula	All ships of squadron failure probability
1	$1 = q + r$	q
2	$1 = q^2 + 2qr + r^2$	$q^2 < q$
3	$1 = q^3 + 3q^2r + 3qr^2 + r^3$	$q^3 << q$
4	$1 = q^4 + 4q^3r + 6q^2r^2 + 4qr^3 + r^4$	$q^4 << q$
	Full failure absence probability	The probability that even one spacecraft will be operative (probability of successful fulfillment of transportation)
1	r	r
2	$r^2 < r$	$2qr + r^2 = 1 - q^2 \geq r$
3	$r^3 << r$	$3q^2r + 3qr^2 + r^3 = 1 - q^3 \geq r$
4	$r^4 << r$	$4q^3r + 6q^2r^2 + 4qr^3 + r^4 = 1 - q^4 \geq r$

Table 2

The formulas of the squadron structure statistical characteristics.

Rescue mission success probability $s < 1$

Squadron's ships number, n	Full probability formula	
2*)	$1 = q^2 + 2qr(1-s) + 2qrs + r^2.$	
3**)	$1 = q^3 + q^2 r[(1-s)^2 + 2(1-s)s] + 2q^2 r(1-s) + 2qr^2(1-s) +$ $+ 2q^2 r(s^2/2 + s) + 2qr^2 s + qr^2 + r$	
4***)	$1 = q^4 + 2q^3 r(1-s^2) + 2q^3 rs^2 + 2q^3 rs + q^2 r^2 + +q^2 r^2(1-s^2) +$ $+q^2 r^2 s^2 + 4q^2 r^2(1-s) + 4q^2 r^2 s + +q^2 r^2 + 2qr^3(1-s) + 2qr^3 s + 2qr^3 + r$	
	Full failure probability	Probability of successful fulfillment of transportation (R_n)
2*)	$q^2 + 2qr(1-s) = 1 - R_2$	$R_2 = 2qrs + r^2$
3**)	$1 - R_3.$	$R_3 = 2q^2 r(s^2/2 + s) + 2qr^2 s + qr^2 + r^3.$
4***)	$1 - R_4$	$R_4 = 2q^3 rs^2 + 2q^3 rs + q^2 r^2 + q^2 r^2 s^2 +$ $+4q^2 r^2 s + q^2 r^2 + 2qr^3 s + 2qr^3 + r^4$

*) Both ships are manned

**) Two ships are originally manned, one ship is unmanned

***) Two ships are originally manned, two ships are unmanned

Table 3.

Calculation results of the Mars mission squadron mode efficiency

Spacecraft's systems reliability r=0,7, failure probability q=0,3			
Squadron's ships number, n	rescue mission success probability s		
	1,0	0,98	0,95
	squadron efficiency, $E_n = q / (1 - R_n)$		
2	3,33	3,05	2,7
3	11,11	7,9	5,5
4	37,04	15,2	8,1
Spacecraft's systems reliability r=0,9, failure probability q=0,1			
	squadron efficiency, $E_n = q / (1 - R_n)$		
2	10	7,35	5,3
3	100	20,2	9,2
4	1000	24,4	9,9

Table 4

Stages of evolutional process in figures (estimations)

Stage	**First**	**Second**	**Third**
Variants of payloads	Components of infrastructure	Inhabitant module on Mars surface	Crew of expedition, 2 cm W -radiation shield
Delivered weight, ton	15 -20	30	42
Power of el. jet engine, kW	125…300	260	950
Specific impulse, sec	3500	3500	4500
Flight duration along the interplanetary trajectory, day	250…350	Up to 350	230, 400 back flight
Starting weight on interplanetary trajectories, ton	22…30	54	90
Starting weight on low Earth orbit, ton		70	110

FIGURES

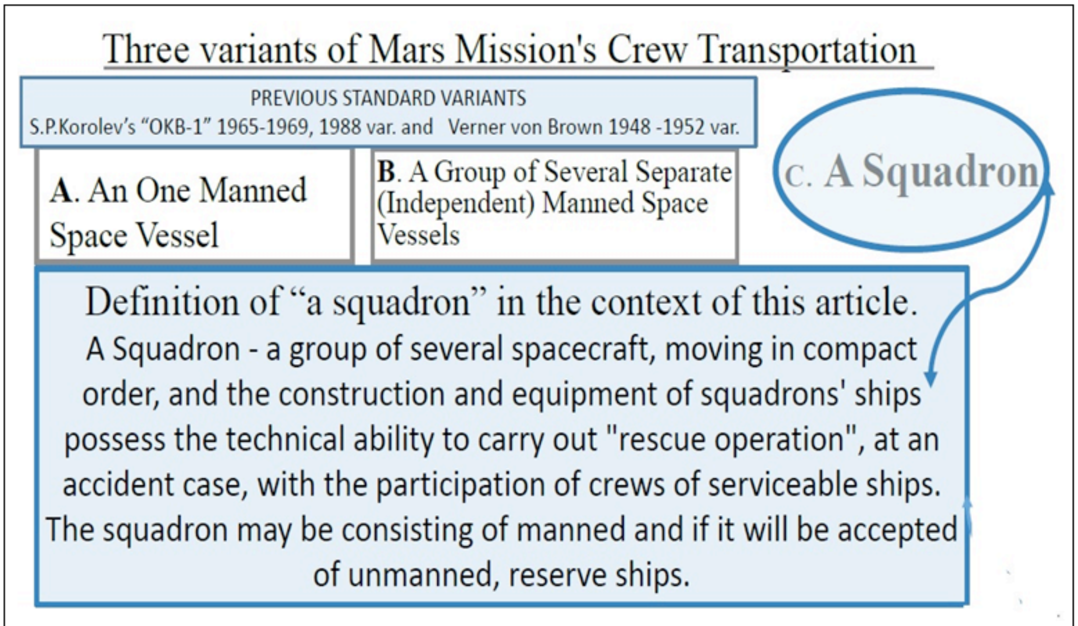
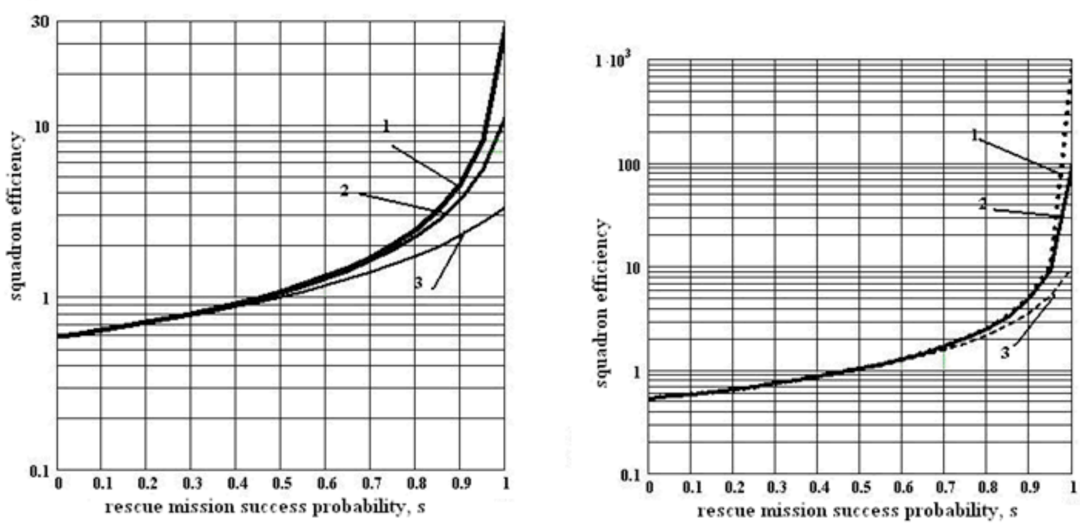


Fig.1. The concept of a squadron



a) b)

Fig. 2. Relation of a squadron efficiency to probability of success of rescue operation.
a) Reliability of spacecraft systems 0.7 (probability of emergency 0.3);
б) Reliability of spacecraft systems 0.9 (probability of emergency 0.1)
1. Numbers of the squadron spacecrafts n=4,
2. Numbers of the squadron spacecrafts n=3;
3. Numbers of the squadron spacecrafts n=2

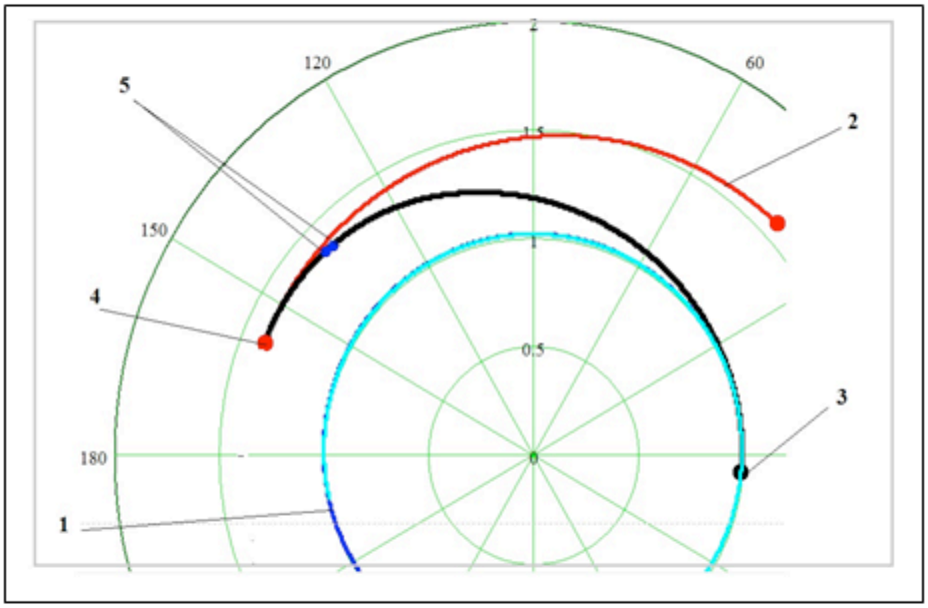


Fig. 3. Rescue operation at an active part of a flight trajectory
1- The orbit of the Earth, 2- a part of Mars orbit,
3- Start point of the interplanetary trajectory, 4- The point of the squadron arriving to Mars, 5 - starting and ending points of the rescue operation (duration 3 days)

Classification of manned expedition to Mars variants

Ранние проекты XX века		
The expedition landed on an unprepared surface of Mars	***Type: Visiting Expedition – 30 days duration***	
Specifics: Technological, energy and motoric components of an Expedition are being mastered in ground tests and by trials in near-Earth space. The expedition is formed in the Earth's orbit and flight to Mars as a whole.	Transport system	
	One ship	Several cargo ships, one manned spacecraft

Some alternative evolutionary variants of the Expedition

Technological, energetic and motor components of the expedition go through stages of development and reliability validation in the process full-scale, deployed in time , creation of infrastructure of expedition's base on Mars and in near-Mars orbit. Then manned flight goes.

Visiting Expedition	One fold scientific expedition	Permanent station on Mars. Exchange crews	Settlement on Mars
Several cargo ships,	Several cargo ships	The transport system of continuous service	
one manned spacecraft	and manned Squadron	Delivery of crews by single ships.	Delivery of crews by Squadron

Fig.4. Classification of manned expedition to Mars variants

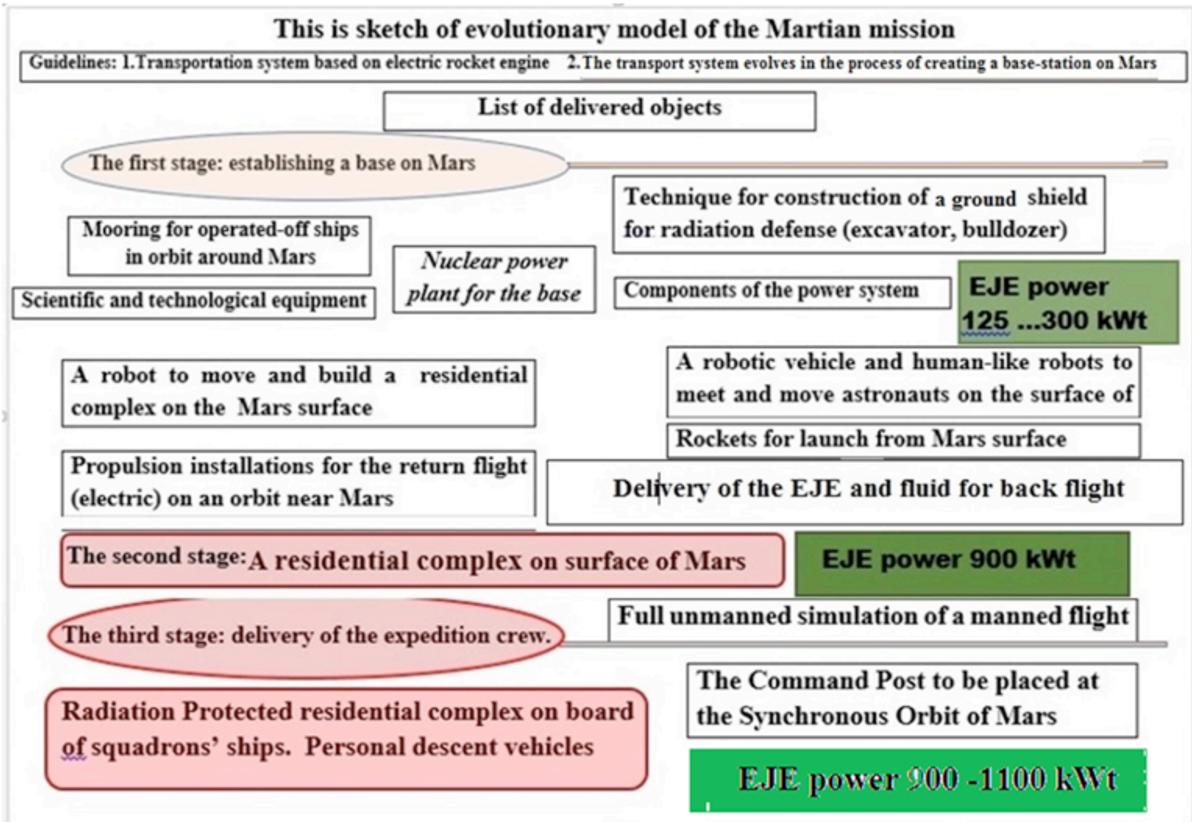


Fig.5. The sketch of evolutionary model of the Manned Mission to Mars