Research Article

# Benefit-function of two- Identical cold standby spacecraft system that integrates a laser-ablation propulsion system with the gas blasting nozzles of a Spacecraft subject to failure of laser-ablation or parachute opening failure

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## Abstract

**Introduction:** Laser ablation is the process of removing material from a solid (or occasionally liquid) surface by irradiating it with a laser beam. At low laser flux, the material is heated by the absorbed laser energy and evaporates or sublimates. At high laser flux, the material is typically converted to a plasma. Usually, laser ablation refers to removing material with a pulsed laser, but it is possible to ablate material with a continuous wave laser beam if the laser intensity is high enough. **MOSCOW:** Scientists and science fiction writers alike have dreamt of aircraft that are propelled by beams of light and not fuel. Now, a new method for improving the thrust-generated by laser-propulsion systems may bring them one step closer to practical use, scientists say. The method, developed by physicists Yuri Rezunkov of the Institute of Optoelectronic Instrument Engineering, Russia and Alexander Schmidt of the Ioffe Physical Technical Institute in Saint Petersburg, Russia has been described in The Optical Society's (OSA) journal Applied Optics. Currently, the maximum speed of a spacecraft is limited by the amount of fuel that it can carry. Achieving higher speeds means that more fuel must be burned - fuel that has to be carried by the craft, researchers said. These burdensome loads can be reduced, however, if a laser located at a remote location and not on the spacecraft were used to provide additional propulsive force. A number of systems have been proposed that can produce such laser propulsion. One of the most promising systems involves a process called laser ablation, in which a pulsed laser beam strikes a surface, heats it up, and burns off material to create a plasma plume - a column of charged particles that flow off the surface. The out flowing of plasma plume generates additional thrust to propel the craft. Rezunkov and Schmidt describe a new system that integrates a laser-ablation propulsion system with the gas blasting nozzles of a spacecraft. Combining the two systems, researchers found, can increase the speed of the gas flow out of the system to supersonic speeds while reducing the amount of burned fuel.
The researchers show that the effectiveness of current laser-propulsion techniques is limited by instability of supersonic gases as they flow through the gas nozzle, as well as production of shock waves that "choke" the nozzle. But those effects can be reduced with the help of a laser-ablation plasma plume. Coupling ablation jet with supersonic gas flow through the nozzle, they found, significantly improves the overall thrust. "These techniques can be used not only for launching small satellites but also for additional acceleration of supersonic aircrafts to achieve Mach 10 and more," Rezunkov said. In this paper we have taken LAF- Laser ablation Failure or POF-Parachute opening failure. When the main unit fails due to Parachute opening failure then cold standby system becomes operative. Parachute opening failure cannot occur simultaneously in both the units and after failure the unit undergoes very costly repair facility immediately. Applying the regenerative point technique with renewal process theory the various reliability parameters MTSF, Availability, Busy period, Benefit-Function analysis have been evaluated.
**Keywords:** Cold Standby Laser ablation Failure, Parachute opening failure, first come first serve, MTSF, Availability, Busy period, Benefit -Function.

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Received Date: 20/10/2014 Accepted Date: 30/10/2014

How to site this article: Ashok Kumar Saini. Benefit-function of two- Identical cold standby spacecraft system that integrates a laser-ablation propulsion system with the gas blasting nozzles of a Spacecraft subject to failure of laser-ablation or parachute opening failure. *International Journal of Statistika and Mathemtika* Nov 2014 to Jan 2015; 12(1): 59-64. http://www.statperson.com (accessed 06 November 2014).

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| Quick Response Code: | Website: www.statperson.com |
| | DOI: 05 November 2014 |


## INTRODUCTION

Russian scientists have proposed a novel way to accelerate a spaceship while in flight – firing a ground-based laser up its backside. The new technique uses a plasma flow caused by laser ablation to increase the exhaust efficiency of a traditional rocket propulsion system, and could theoretically accelerate an aircraft beyond Mach 10. In the process called laser ablation, a super high powered, focused laser beam can strike the surface of an object in space, and burn off that surface material, producing a plume of charged plasma particles that generates thrust. It's a process that has been considered as a way to potentially blast space debris out of Earth orbit, but in this case it's seen as a way to provide extra thrust for a spaceship, without having to carry the primary energy supply on board the ship. Mind you, the ship does need to carry enough extra surface metal to be burned off in the ablation process. A team of Russian scientists led by Yuri Rezunkov at the Institute of Optoelectronic Instrument Engineering, Russia has found a new way to use laser ablation to provide additional acceleration – by using it to increase the efficiency and thrust of regular gas blasting rockets. Stochastic behavior of systems operating under changing environments has widely been studied.. Dhillon, B.S. and Natesan, J. (1983) studied an outdoor power systems in fluctuating environment. Kan Cheng (1985) has studied reliability analysis of a system in a randomly changing environment. Jinhua Cao (1989) has studied a man machine system operating under changing environment subject to a Markov process with two states. The change in operating conditions viz. fluctuations of voltage, corrosive atmosphere, very low gravity etc. may make a system completely inoperative. Severe environmental conditions can make the actual mission duration longer than the ideal mission duration.

### Soyuz 1: Parachute opening failure

24 April 1967 The one-day mission had been plagued by a series of mishaps with the new spacecraft type, culminating with its parachute not opening properly after atmospheric reentry. Komarov was killed when the capsule hit the ground at high speed. The Soyuz 1 crash site coordinates are 51.3615°N 59.5622°E, 3 kilometres (1.9 mi) west of Karabutak, Province of Orenburg in the Russian Federation, about 275 kilometres (171 mi) east-southeast of Orenburg. In a small park on the side of the road is a memorial monument: a black column with a bust of Komarov at the top. In this paper we have taken Laser ablation Failure or Parachute opening failure when the main operative unit fails then cold standby system becomes operative. Parachute opening failure cannot occur simultaneously in both the units and after failure the unit undergoes repair facility of very high cost in case of Parachute opening failure immediately. The repair is done on the basis of first fail first repaired.

### Assumptions

$\lambda_1, \lambda_2,$ are failure rates for constant Laser ablation Failure, Parachute opening failure rate, respectively. The CDF of repair time distribution of Type I and Type II are $G_1(t)$ and $G_2(t)$.

1. The Parachute opening failure is non-instantaneous and it cannot come simultaneously in both the units.
2. The repair starts immediately after the failure due to Laser ablation Failure or Parachute opening failure works on the principle of first fail first repaired basis.
3. The repair facility does no damage to the units and after repair units are as good as new.
4. The switches are perfect and instantaneous.
5. All random variables are mutually independent.
6. When both the units fail, we give priority to operative unit for repair.
7. Repairs are perfect and failure of a unit is detected immediately and perfectly.
8. The system is down when both the units are non-operative.

### Notations

$\lambda_1, \lambda_2$ are the **failure rates** due to Laser ablation Failure, Parachute opening failure rate, respectively. $G_1(t)$, $G_2(t)$ – repair time distribution Type -I, Type-II due to Laser ablation Failure, Parachute opening failure rate, respectively.
p, q - probability of Laser ablation Failure, Parachute opening failure respectively such that p+ q=1
$M_i(t)$ System having started from state I is up at time t without visiting any other regenerative state
$A_i(t)$ state is up state as instant t
$R_i(t)$ System having started from state I is busy for repair at time t without visiting any other regenerative state.
$B_i(t)$ the server is busy for repair at time t.
$H_i(t)$ Expected number of visits by the server for repairing given that the system initially starts from regenerative state i

## SYMBOLS FOR STATES OF THE SYSTEM

**Superscripts: O, CS, LAF, POF** Operative, Cold Standby, **Laser ablation Failure**, **Parachute opening failure** respectively
**Subscripts:** nlaf, laf, pof, ur, wr, uR
No **Laser ablation Failure**, **Laser ablation Failure**, **Parachute opening failure,** under repair, waiting for repair, under repair continued from previous state respectively
**Up states:** 0, 1, 2, 7, 8;
**Down states:** 3, 4, 5, 6
**Regeneration point:** 0, 1, 2, 7, 8

### STATES OF THE SYSTEM

**0($O_{nlaf}$, $CS_{nlaf}$)**
One unit is operative and the other unit is cold standby and there is no Laser ablation Failure in both the units.
**1($LAF_{laf, ur}$, $O_{nlaf}$)**
The operating unit fails due to **Laser ablation Failure** and is under repair immediately of very costly Type- I and standby unit starts operating with no **Laser ablation Failure**.
**2($POF_{pof, ur}$, $O_{nlaf}$)**
The operative unit fails due to POF resulting from Parachute opening failure and undergoes repair of type II and the standby unit becomes operative with no **Laser ablation Failure**.
**3($LAF_{laf,uR}$, $POF_{pof,wr}$)**
The first unit fails due to **Laser ablation Failure** and under very costly Type-1repair is continued from state 1 and the other unit fails due to POF resulting from Parachute opening failure and is waiting for repair of Type -II.
**4($LAF_{laf,uR}$, $LAF_{laf,wr}$)**
The repair of the unit is failed due to LAF resulting from **Laser ablation Failure** is continued from state 1and the other unit failed due to LAF resulting from **Laser ablation Failure** is waiting for repair of Type-I.
**5($POF_{pof, uR}$, $POF_{pof, wr}$)**
The operating unit fails due to Parachute opening failure (POF mode) and under repair of Type - II continues from the state 2 and the other unit fails also due to Parachute opening failure is waiting for repair of Type- II.
**6($POF_{pof,uR}$, $LAF_{nlaf,wr}$)**
The operative unit fails due to POF resulting from Parachute opening failure and under repair continues from state 2 of Type –II and the other unit is failed due to LAF resulting from **Laser ablation Failure** and under very costly Type-1
**7($O_{nlaf}$, $LAF_{laf,ur}$)**
The repair of the unit failed due to operative unit fails due to LAF resulting from Laser ablation Failure is completed and there is no Laser ablation Failure and the other unit is failed due to LAF resulting from **Laser ablation Failure** is under repair of very costly Type-1
**8($O_{nlaf}$, $POF_{pof,ur}$)**
The repair of the unit failed due to LAF resulting from laser ablation failure is completed and there is no Laser ablation Failure and the other unit is failed due to POF resulting from Parachute opening failure is under repair of Type-II.

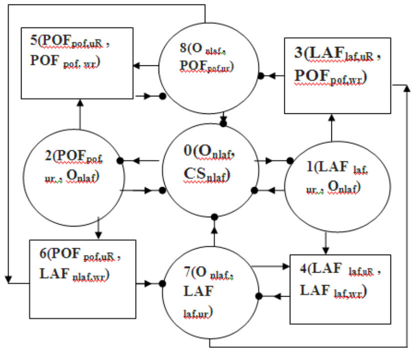


**Figure 1:** The State Transition Diagram

● Rregeneration point ○ Up State □ Down State

## TRANSITION PROBABILITIES

Simple probabilistic considerations yield the following expressions:

$p_{01} = p,\ p_{02} = q,$

$p_{10} = pG_1^*(\lambda_1) + q\,G_1^*(\lambda_2) = p_{70},\ p_{20} = pG_2^*(\lambda_1) + q\,G_2^*(\lambda_2) = p_{80},$

$p_{11}^{(3)} = p(1 - G_1^*(\lambda_1)) = p_{14} = p_{71}^{(4)},\ p_{28}^{(5)} = q(1 - G_2^*(\lambda_2)) = p_{25} = p_{82}^{(5)}$ (1)

We can easily verify that

$p_{01} + p_{02} = 1,\ p_{10} + p_{17}^{(4)} (= p_{14}) + p_{18}^{(3)} (= p_{13}) = 1,$

$p_{80} + p_{82}^{(5)} + p_{87}^{(6)} = 1$ (2)

And mean sojourn time is

$\mu_0 = E(T) = \int_0^\infty P[T > t]dt$

### Mean Time to System Failure

$Ø_0(t) = Q_{01}(t)[s]\, Ø_1(t) + Q_{02}(t)[s]\, Ø_2(t)$

$Ø_1(t) = Q_{10}(t)[s]\, Ø_0(t) + Q_{13}(t) + Q_{14}(t)$

$Ø_2(t) = Q_{20}(t)[s]\, Ø_0(t) + Q_{25}(t) + Q_{26}(t)$ (3-5)

We can regard the failed state as absorbing

Taking Laplace-Stiljes transform of eq. (3-5) and solving for

$ø_0^*(s) = N_1(s) / D_1(s)$ (6)

where

$N_1(s) = Q_{01}^*[\,Q_{13}^*(s) + Q_{14}^*(s)\,] + Q_{02}^*[\,Q_{25}^*(s) + Q_{26}^*(s)\,]$

$D_1(s) = 1 - Q_{01}^* Q_{10}^* - Q_{02}^* Q_{20}^*$

Making use of relations (1) and (2) it can be shown that $ø_0^*(0) = 1$, which implies that $ø_0(t)$ is a proper distribution.

$$MTSF = E[T] = \frac{d}{ds} ø_0^{*}(s)\Big|_{s=0} = (D_1'(0) - N_1'(0)) / D_1(0)$$

$= (\mu_0 + p_{01}\mu_1 + p_{02}\mu_2) / (1 - p_{01}p_{10} - p_{02}p_{20})$

where

$\mu_0 = \mu_{01} + \mu_{02},\ \mu_1 = \mu_{01} + \mu_{17}^{(4)} + \mu_{18}^{(3)},\ \mu_2 = \mu_{02} + \mu_{27}^{(6)} + \mu_{28}^{(5)}$

## AVAILABILITY ANALYSIS

Let $M_i(t)$ be the probability of the system having started from state i is up at time t without making any other regenerative state. By probabilistic arguments, we have

$M_0(t) = e^{-\lambda_1 t}\overline{e^{-\lambda_2 t}},\ M_1(t) = p\,G_1(t)\,e^{-(\lambda_1 + \lambda_2)} = M_7(t)$

$M_2(t) = q\,G_2(t)\,\overline{e}^{-(\lambda_1 + \lambda_2)} = M_8(t)$

The point wise availability $A_i(t)$ have the following recursive relations

$A_0(t) = M_0(t) + q_{01}(t)[c]A_1(t) + q_{02}(t)[c]A_2(t)$

$A_1(t) = M_1(t) + q_{10}(t)[c]A_0(t) + q_{18}^{(3)}(t)[c]A_8(t) + q_{17}^{(4)}(t)[c]A_7(t),$

$A_2(t) = M_2(t) + q_{20}(t)[c]A_0(t) + [q_{28}^{(5)}(t)[c]\ A_8(t) + q_{27}^{(6)}(t)]\ [c]A_7(t)$

$A_7(t) = M_7(t) + q_{70}(t)[c]A_0(t) + [q_{71}^{(4)}(t)[c]\ A_1(t) + q_{78}^{(3)}(t)]\ [c]A_8(t)$ $A_8(t) = M_8(t) + q_{80}(t)[c]A_0(t) +[q_{82}^{(5)}(t)[c]\ A_2(t) + q_{87}^{(6)}(t)]\ [c]A_7(t)$ (7-11)

Taking Laplace Transform of eq. (7-11) and solving for $\hat{A}_0(s)$

$$\hat{A}_0(s) = N_2(s) / D_2(s) \quad (12)$$

where

$N_2(s) = \hat{M}_0 (1 - \hat{q}_{78}^{(3)} - \hat{q}_{87}^{(6)}) - \hat{q}_{82}^{(5)}(\hat{q}_{27}^{(6)} \hat{q}_{78}^{(3)} + \hat{q}_{28}^{(5)} - \hat{q}_{71}^{(4)}$
$(\hat{q}_{17}^{(4)} + \hat{q}_{87}^{(6)} \hat{q}_{18}^{(3)}) + \hat{q}_{71}^{(4)} \hat{q}_{82}^{(5)} (\hat{q}_{17}^{(4)} - \hat{q}_{27}^{(6)} \hat{q}_{18}^{(3)})] + \hat{q}_{01}[\hat{M}_1(1 -$
$\hat{q}_{78}^{(3)} \hat{q}_{87}^{(6)}) + \hat{q}_{71}^{(4)}(\hat{M}_7 + \hat{q}_{78}^{(3)} \hat{M}_8) + \hat{q}_{18}^{(3)}(\hat{M}_7 \hat{q}_{87}^{(6)} - \hat{M}_8) -$
$\hat{q}_{82}^{(5)}(\hat{M}_1(\hat{q}_{27}^{(6)} \hat{q}_{78}^{(3)} + \hat{q}_{28}^{(5)}) + \hat{q}_{17}^{(4)}(-\hat{M}_2(\hat{q}_{78}^{(3)} + \hat{M}_7 \hat{q}_{28}^{(5)}) -$
$\hat{q}_{18}^{(3)}(\hat{M}_2 + \hat{M}_7 \hat{q}_{27}^{(6)})\}]\ \hat{q}_{02}[\hat{M}_2(1 - \hat{q}_{78}^{(3)} \hat{q}_{87}^{(6)}) + \hat{q}_{27}^{(6)}($
$\hat{M}_7 + \hat{q}_{78}^{(3)} \hat{M}_8) + \hat{q}_{28}^{(5)}(\hat{M}_7 \hat{q}_{87}^{(6)} + \hat{M}_8) - \hat{q}_{71}^{(4)}(\hat{M}_1(-\hat{q}_{27}^{(6)} - \hat{q}_{28}^{(5)} +$
$\hat{q}_{87}^{(6)}) + \hat{q}_{17}^{(4)}(\hat{M}_2 + \hat{q}_{28}^{(5)} \hat{M}_8) - \hat{q}_{18}^{(3)}(-\hat{M}_2 \hat{q}_{87}^{(6)} + \hat{M}_8 \hat{q}_{27}^{(6)})\}]$
$\hat{q}_{18}^{(3)}(\hat{M}_2 + \hat{M}_7 \hat{q}_{27}^{(6)})\}]$

$D_2(s) = (1 - \hat{q}_{78}^{(3)} - \hat{q}_{87}^{(6)}) - \hat{q}_{82}^{(5)}(\hat{q}_{27}^{(6)} \hat{q}_{78}^{(3)} + \hat{q}_{28}^{(5)}) - \hat{q}_{71}^{(4)}$
$(\hat{q}_{17}^{(4)} + \hat{q}_{87}^{(6)} \hat{q}_{18}^{(3)}) + \hat{q}_{71}^{(4)} \hat{q}_{82}^{(5)} (\hat{q}_{17}^{(4)} \hat{q}_{28}^{(5)} - \hat{q}_{18}^{(3)})] + \hat{q}_{01}[-\hat{q}_{10}(1 -$
$\hat{q}_{78}^{(3)} \hat{q}_{87}^{(6)}) - \hat{q}_{71}^{(4)}(\hat{q}_{70} + \hat{q}_{78}^{(3)} \hat{q}_{80}) - \hat{q}_{18}^{(3)}(\hat{q}_{70} \hat{q}_{87}^{(6)} - \hat{q}_{80}) -$
$\hat{q}_{82}^{(5)}(-\hat{q}_{10}(\hat{q}_{27}^{(6)} \hat{q}_{78}^{(3)} + \hat{q}_{28}^{(5)}) + \hat{q}_{17}^{(4)}(\hat{q}_{20}(\hat{q}_{78}^{(3)} - \hat{q}_{70} \hat{q}_{28}^{(5)}) +$
$\hat{q}_{18}^{(3)}(\hat{q}_{20} + \hat{q}_{70} \hat{q}_{27}^{(6)})\}]\ \hat{q}_{02}[-\hat{q}_{20}(1 - \hat{q}_{78}^{(3)} \hat{q}_{87}^{(6)}) - \hat{q}_{27}^{(6)}(\hat{q}_{70} + \hat{q}_{78}^{(3)} \hat{q}_{80}) -$
$\hat{q}_{28}^{(5)}(\hat{q}_{70} \hat{q}_{87}^{(6)} + \hat{q}_{80}) - \hat{q}_{71}^{(4)}(\hat{q}_{10}(\hat{q}_{27}^{(6)} + \hat{q}_{28}^{(5)} \hat{q}_{87}^{(6)}) - \hat{q}_{17}^{(4)}(\hat{q}_{20} -$
$\hat{q}_{28}^{(5)} \hat{q}_{80}) - \hat{q}_{18}^{(3)}(\hat{q}_{20} \hat{q}_{87}^{(6)} + \hat{q}_{80} \hat{q}_{27}^{(6)})\}]$

(Omitting the arguments s for brevity)

The steady state availability

$$A_0 = \lim_{t\to\infty}[A_0(t)] = \lim_{s\to 0}[s\,\hat{A}_0(s)] = \lim_{s\to 0}\frac{s\,N_2(s)}{D_2(s)}$$

Using L' Hospitals rule, we get

$$A_0 = \lim_{s\to 0}\frac{N_2(s)+s\ N_2'(s)}{D_2'(s)} = \frac{N_2(0)}{D_2'(0)} \quad (13)$$

The expected up time of the system in (0, t] is

$$\lambda_u(t) = \int_0^\infty A_0(z)\,dz \text{ So that } \bar{\lambda}_u(s) = \frac{\hat{A}_0(s)}{s} = \frac{N_2(S)}{SD_2(S)} \quad (14)$$

The expected down time of the system in (0, t] is

$$\lambda_d(t) = t - \lambda_u(t) \text{ So that } \bar{\lambda}_d(s) = \frac{1}{s^2} - \bar{\lambda}_u(s) \quad (15)$$

**The expected busy period of the server when there is POF-failure resulting from Parachute opening failure or LAF- failure due to Laser ablation Failure in (0,t]**

$R_0(t) = q_{01}(t)[c]R_1(t) + q_{02}(t)[c]R_2(t)$
$R_1(t) = S_1(t) + q_{10}(t)[c]R_0(t) + q_{18}^{(3)}(t)[c]\ R_8(t) + q_{17}^{(4)}(t)[c]R_7(t)$
$R_2(t) = S_2(t) + q_{20}(t)[c]R_0(t) + q_{28}^{(5)}(t)\ R_8(t) + q_{27}^{(6)}(t)][c]R_7(t)$
$R_7(t) = S_7(t) + q_{70}(t)[c]R_0(t) + Q_{71}^{(4)}(t)\ R_1(t) + q_{78}^{(3)}(t)][c]R_8(t)$
$R_8(t) = S_8(t) + q_{80}(t)[c]R_0(t) + Q_{82}^{(5)}(t)\ R_2(t) + q_{87}^{(6)}(t)][c]R_7(t)$ (16-20)

Taking Laplace Transform of eq. (16-20) and solving for $\bar{R}_0(s)$

$$\bar{R}_0(s) = N_3(s) / D_2(s) \quad (21)$$

where

$N_3(s) = \hat{q}_{01}[\hat{S}_1(1 - \hat{q}_{78}^{(3)} \hat{q}_{87}^{(6)}) + \hat{q}_{71}^{(4)}(\hat{S}_7 + \hat{q}_{78}^{(3)} \hat{S}_8) + \hat{q}_{18}^{(3)}(\hat{S}_7$

$\hat{q}_{87}^{(6)} - \hat{S}_8)] - \hat{q}_{01}\hat{q}_{82}^{(5)}(\hat{S}_1 \hat{q}_{27}^{(6)} \hat{q}_{78}^{(3)} + \hat{q}_{28}^{(5)}) + \hat{q}_{17}^{(4)}(\hat{S}_2 \hat{q}_{78}^{(3)} + \hat{S}_7 \hat{q}_{28}^{(5)}) -$
$\hat{q}_{18}^{(3)}(\hat{S}_2 + \hat{S}_7\hat{q}_{27}^{(6)})] + \hat{q}_{02}[\hat{S}_2(1 - \hat{q}_{78}^{(3)}\hat{q}_{87}^{(6)}) + \hat{q}_{27}^{(6)}(\hat{S}_7 + \hat{q}_{78}^{(3)}\hat{S}_8) + \hat{q}_{28}^{(5)}(\hat{S}_7\hat{q}_{87}^{(6)} + \hat{S}_8) - \hat{q}_{02}\hat{q}_{71}^{(4)}(\hat{S}_1(-\hat{q}_{27}^{(6)} -$
$\hat{q}_{28}^{(5)}\hat{q}_{87}^{(6)}\hat{q}_{17}^{(4)}(\hat{S}_2 + \hat{q}_{28}^{(5)}\hat{S}_8) - \hat{q}_{18}^{(3)}(-\hat{S}_2\hat{q}_{87}^{(6)} + \hat{S}_8\hat{q}_{27}^{(6)})]$
and
$D_2(s)$ is already defined.
(Omitting the arguments s for brevity)

In the long run, $R_0 = \frac{N_3(0)}{D_2'(0)}$ (22)

The expected period of the system under POF-failure resulting from Parachute opening failure or LAF- failure due to Laser ablation Failure in (0,t] is

$\lambda_{rv}(t) = \int_0^\infty R_0(z)dz$ So that $\overline{\lambda_{rv}}(s) = \frac{\hat{R}_0(s)}{s}$

**The expected number of visits by the repairman for repairing the identical units in (0, t]**

$H_0(t) = Q_{01}(t)[s][1+ H_1(t)] + Q_{02}(t)[s][1+ H_2(t)]$
$H_1(t) = Q_{10}(t)[s]H_0(t)] + Q_{18}^{(3)}(t)[s]\ H_8(t) + Q_{17}^{(4)}(t)]\ [s]H_7(t),$
$H_2(t) = Q_{20}(t)[s]H_0(t) + Q_{28}^{(5)}(t)\ [s]\ H_8(t) + Q_{27}^{(6)}(t)]\ [c]H_7(t)$
$H_7(t) = Q_{70}(t)[s]H_0(t) + Q_{71}^{(4)}(t)\ [s]\ H_1(t) + Q_{78}^{(3)}(t)]\ [c]H_8(t)$
$H_8(t) = Q_{80}(t)[s]H_0(t) + Q_{82}^{(5)}(t)\ [s]\ H_2(t) + Q_{87}^{(6)}(t)]\ [c]H_7(t)$ (23-27)

Taking Laplace Transform of eq. (23-27) and solving for $H_0^*(s)$

$H_0^*(s) = N_4(s) / D_3(s)$ (28)

In the long run, $H_0 = N_4(0) / D_3'(0)$ (29)

## BENEFIT- FUNCTION ANALYSIS

The Benefit-Function analysis of the system considering mean up-time, expected busy period of the system under Laser ablation Failure or Parachute opening failure, expected number of visits by the repairman for unit failure.

The expected total Benefit-Function incurred in (0, t] is

C (t) = Expected total revenue in (0, t]

- expected busy period of the system under failure due to Laser ablation Failure or failure due to Parachute opening failure for repairing the units in (0,t ]
- expected number of visits by the repairman for repairing of identical the units in (0,t]

The expected total cost per unit time in steady state is

$C = \lim_{t\to\infty}(C(t)/t) = \lim_{s\to 0}(s^2 C(s))$
$= K_1A_0 - K_2R_0 - K_3H_0$
where
**$K_1$:** revenue per unit up-time,
**$K_2$:** cost per unit time for which the system is under repair of type- I or type- II
**$K_3$:** cost per visit by the repairman for units repair.

## CONCLUSION

After studying the system, we have analyzed graphically that when the failure rate due to Parachute opening failure or failure rate due to Laser ablation Failure increases, the MTSF and steady state availability decreases and the Benefit-function decreased as the failure increases.

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Source of Support: None Declared
Conflict of Interest: None Declared