Profit-function of two- identical cold standby satellite system subject to failure due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle and failure due to developmental flight, payload placed into lower than planned orbit

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Abstract In this paper we have taken failure due to unexpected large disturbance at the second stage separation resulting in a suborbital flight of the vehicle and failure due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit. When the main unit fails then cold standby system becomes operative. Failure payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit cannot occur simultaneously in both the units and after failure the unit undergoes Type-I or Type-II or Type-III 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, sub-orbital flight of the vehicle, failure due to Developmental Flight, payload placed into

**Keywords:** Cold Standby, sub-orbital flight of the vehicle, failure due to Developmental Flight, payload placed into lower than planned orbit, first come first serve, MTSF, Availability, Busy period, Benefit -Function.

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# **INTRODUCTION**

The following list gives a detailed record of the launches taken place in **Satish Dhawan Space Centre**. It is the main satellite launch centre for the Indian Space Research Organisation (ISRO). It is located in Sriharikota, Andhra Pradesh, 80 km (50 mi) north of Chennai. Originally called **Sriharikota High Altitude Range (SHAR)**, an acronym ISRO have

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retained to the present day) and then **Sriharikota Launching Range**, the centre was renamed in 2002 after the death of ISRO's former chairman Satish Dhawan. No. of launches *As of 18 December 2014*,

Total no. of launches = 45 Mission status wise Successful launches = 33, Launches which left payloads usable = 37, Failed launches = 8 Rocket used wise SLV = 4 (1 failure, 1 partial failure and 2 successful), ASLV = 4 (2 failures, 1 partial failure and 1 successful) PSLV = 28 (1 failure, 1 partial failure and 26 successful), GSLV = 9 (4 Failures, 1 partial failure and 4 successful) Launch Pad used wise SLV Launch Pad = 8 (3 Failures, 2 partial failure and 3 successful) First Launch Pad = 25 (2 Failures, 1 partial failure and 22 successful) Second Launch Pad = 12 (3 Failures, 1 partial failure and 8 successful)

20 September 1993	First	PSLV	D1	Failure	Unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle. One of the retro rockets designed to pull the burnt second stage away from the third stage failed.
18 April 2001	First	GSLV Mk I(a)	D1	Failure	Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit.

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. In this paper we have taken failure due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle and failure due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit. When the main operative unit fails then cold standby system becomes operative. Failure due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit cannot occur simultaneously in both the units and after failure the unit undergoes repair facility of Type- II by ordinary repairman or Type III by multispecialty repairman in case of failure due to Developmental Flight, and did not have sufficient fuel to reach a usable orbit, and did not have sufficient fuel to reach a usable orbit, and did not have sufficient fuel to reach a usable orbit cannot occur simultaneously in both the units and after failure the unit undergoes repair facility of Type- II by ordinary repairman or Type III by multispecialty repairman in case of failure due to Developmental Flight, and did not have sufficient fuel to reach a usable orbit fail first repaired.

#### ASSUMPTIONS

- 1.  $\lambda_{1,}\lambda_{2}$  are constant failure rates due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle and failure due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit respectively. The CDF of repair time distribution of Type I, Type II and multispecialty repairmen Type-III are G<sub>1</sub>(t), G<sub>2</sub>(t) and G<sub>3</sub>(t).
- 2. The failure due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit is non-instantaneous and it cannot come simultaneously in both the units.
- 3. The repair starts immediately after critical failure of ISS without astronauts and works on the principle of first fail first repaired basis.
- 4. The repair facility does no damage to the units and after repair units are as good as new.
- 5. The switches are perfect and instantaneous.
- 6. All random variables are mutually independent.
- 7. When both the units fail, we give priority to operative unit for repair.
- 8. Repairs are perfect and failure of a unit is detected immediately and perfectly.
- 9. The system is down when both the units are non-operative.

#### Notations

 $\lambda_1$ ,  $\lambda_2$  - failure rates for failure due to unexpected large disturbance at the second stage separation resulting in a suborbital flight of the vehicle and failure due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit respectively.  $G_1(t)$ ,  $G_2(t)$ ,  $G_3(t)$  – repair time distribution Type –I, Type-II, Type III due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle and due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbite to, repair by the multispecialty repairman respectively. p, q - probability of failure due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle and failure due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit respectively such that p+ q=1

M<sub>i</sub>(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 at instant t

R<sub>i</sub>(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, SOFF, LPOF,

Operative, Cold Standby, failure due to unexpected large disturbance at the second stage separation resulting in a suborbital flight of the vehicle and failure due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit respectively

Subscripts: nsoff, soff, lpof, ur, wr, uR

No failure due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle, failure due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle, failure due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit, under repair, waiting for repair, under repair continued from previous state respectively Up states -0, 1, 2, 3, 8, 9; Down states -4, 5, 6, 7;

regeneration point - 0,1,2, 3, 8, 9

## **STATES OF THE SYSTEM**

### 0(Onsoff, CSnsoff)

One unit is operative and the other unit is cold standby and there is no failure due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle in both the units.

#### 1(SOFF soff, url, Onsoff)

The operating unit fails due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle and is under repair immediately of Type- I and standby unit starts operating with no failure due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle.

## 2(LPOF<sub>lpof, urII</sub>, O<sub>nsoff</sub>)

The operative unit fails due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit and undergoes repair of type II and the standby unit becomes operative with no failure due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle.

#### 3(LPOF<sub>lpof, urIII</sub>, O<sub>nsoff</sub>)

The first unit fails due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit and under Type-III multispecialty repairman and the other unit is operative with no failure due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle.

#### 4(SOFF soff,uR1, SOFF soff,wrI)

The unit failed due to SOFF resulting from unexpected large disturbance at the second stage separation resulting in a suborbital flight of the vehicle and is under repair immediately of Type- I is under repair of Type- I continued from state land the other unit failed due to SOFF resulting from fails due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle and is waiting for repair of Type-I.

#### 5(SOFF soff,uR1, LPOFlpof, wrII)

The unit failed due to SOFF resulting from unexpected large disturbance at the second stage separation resulting in a suborbital flight of the vehicle and is under repair of Type- I continued from state 1 and the other unit fails due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit is waiting for repair of Type- II.

6(LPOF<sub>lpof, uRII</sub>, SOFF<sub>soff, wrI</sub>)

The operative unit fails due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit and under repair continues from state 2 of Type –II and the other unit is failed due to SOFF resulting from unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle and waiting for repair of Type-I

### 7(LPOF<sub>lpof, uRII</sub>, SOFF<sub>soff,wrII</sub>)

The one unit fails due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit continued to be under repair of Type II and the other unit failed due to SOFF resulting from unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle is waiting for repair of Type-II

#### 8(SOFF<sub>soff,urIII</sub>, LPOF<sub>lpof, wrII</sub>)

The one unit failure due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle is under multispecialty repair of Type-III and the other unit is failed due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit is waiting for repair of Type-II.

#### 9(SOFF<sub>soff,urIII</sub>, LPOF<sub>lpof, wrI</sub>)

The one unit failure due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle is under multispecialty repair of Type-III and the other unit is failed due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit is waiting for repair of TypeI



#### **TRANSITION PROBABILITIES**

Simple probabilistic considerations yield the following expressions:  $p_{01} = \lambda_1 / \lambda_1 + \lambda_2, p_{02} = \lambda_2 / \lambda_1 + \lambda_2, p_{10} = pG_1^*(\lambda_1) + qG_2^*(\lambda_2),$   $p_{14} = p - pG_1^*(\lambda_1) = p_{11}^{(4)}, p_{15} = q - qG_1^*(\lambda_2) = p_{12}^{(5)},$   $p_{23} = pG_2^*(\lambda_1) + qG_2^*(\lambda_2), p_{26} = p - pG_2^*(\lambda_1) = p_{29}^{(6)},$   $p_{27} = q - qG_2^*(\lambda_2) = p_{28}^{(7)}, p_{30} = p_{82} = p_{91} = 1$ We can easily verify that  $p_{01} + p_{02} = 1, p_{10} + p_{14} (=p_{11}^{(4)}) + p_{15} (=p_{12}^{(5)}) = 1,$   $p_{23} + p_{26} (=p_{29}^{(6)}) + p_{27} (=p_{28}^{(7)}) = 1$ And mean sojourn time is  $\mu_0 = E(T) = \int_{U}^{U} P[T > t] dt$ 

#### **MEAN TIME TO SYSTEM FAILURE**

$$\begin{split} & \emptyset_0(t) = Q_{01}(t)[s] \ \emptyset_1(t) + Q_{02}(t)[s] \ \emptyset_2(t) \\ & \emptyset_1(t) = Q_{10} \ (t)[s] \ \emptyset_0(t) + Q_{14}(t) + Q_{15}(t) \\ & \emptyset_2(t) = Q_{23} \ (t)[s] \ \emptyset_3(t) + Q_{26}(t) + Q_{27}(t) \\ & \emptyset_3(t) = Q_{30}(t)[s] \ \emptyset_0(t) \end{split}$$

(3-6)

(1)

(2)

We can regard the failed state as absorbing

Taking Laplace-Stiljes transform of eq. (3-6) and solving for  $\phi_0^*(s) = N_1(s) / D_1(s)$  (6) where  $N_1(s) = Q_{01}^* [Q_{14}^*(s) + Q_{15}^*(s)] + Q_{02}^* [Q_{26}^*(s) + Q_{27}^*(s)]$   $D_1(s) = 1 - Q_{01}^* Q_{10}^* - Q_{02}^* Q_{23}^* Q_{30}^*$ Making use of relations (1) & (2) it can be shown that  $\phi_0^*(0) = 1$ , which implies that  $\phi_0(t)$  is a proper distribution.

MTSF = E[T] = 
$$\frac{d}{ds} \left. \overset{\circ}{\mathbf{0}}_{0}^{(s)} \right|_{s=0} = (D_{1}(0) - N_{1}(0)) / D_{1}(0)$$

=( $\mu_0 + p_{01} \mu_1 + p_{02} \mu_2$ )/(1 -  $p_{01} p_{10} - p_{02} p_{23}$ ) where  $\mu_0 = \mu_{01} + \mu_{02},$  $\mu_1 = \mu_{10} + \mu_{11}^{(4)} + \mu_{12}^{(5)},$  $\mu_2 = \mu_{23} + \mu_{28}^{(7)} + \mu_{29}^{(6)}$ 

### **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

$$\begin{split} M_{0}(t) &= e^{-\lambda_{1} t} e^{-\lambda_{2} t} M_{1}(t) = p G_{1}(t) e^{-\lambda_{1} t} \\ M_{2}(t) &= q G_{2}(t), M_{3}(t) = G_{3}(t) \\ \text{The point wise availability } A_{i}(t) have the following recursive relations \\ A_{0}(t) &= M_{0}(t) + q_{01}(t)[c]A_{1}(t) + q_{02}(t)[c]A_{2}(t) \\ A_{1}(t) &= M_{1}(t) + q_{10}(t)[c]A_{0}(t) + q_{12}^{(5)}(t)[c]A_{2}(t) + q_{11}^{(4)}(t)[c]A_{1}(t), \\ A_{2}(t) &= M_{2}(t) + q_{23}(t)[c]A_{3}(t) + q_{28}^{(7)}(t)[c] A_{8}(t) + q_{29}^{(6)}(t)] [c]A_{9}(t) \\ A_{3}(t) &= M_{3}(t) + q_{30}(t)[c]A_{0}(t) \\ A_{8}(t) &= q_{82}(t)[c]A_{2}(t) \\ A_{9}(t) &= q_{91}(t)[c]A_{1}(t) \end{split}$$
(7-11)

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

$$\mathbf{\hat{h}}_{0}(\mathbf{s}) = N_{2}(\mathbf{s}) / D_{2}(\mathbf{s})$$
 (12)

where

 $N_{2}(s) = \hat{M}_{0} [\{1 - \hat{q}_{11}^{(4)}\} \{1 - \hat{q}_{28}^{(7)} \hat{q}_{82}\} - \hat{q}_{12}^{(5)} \hat{q}_{29}^{(6)} \hat{q}_{91}] + \hat{q}_{01} [\hat{M}_{1} \{1 - \hat{q}_{28}^{(7)} \hat{q}_{82}\} + \hat{q}_{12}^{(5)} \hat{q}_{23}^{(2)} \hat{M}_{3}] + \hat{q}_{02} [\{\hat{q}_{23} \hat{M}_{3} + \hat{M}_{2}\} \{1 - \hat{q}_{11}^{(4)}\} + \hat{q}_{29}^{(6)} \hat{q}_{91} \hat{M}_{1}]$   $D_{2}(s) = \{1 - \hat{q}_{11}^{(4)}\} \{1 - \hat{q}_{28}^{(7)} \hat{q}_{82}\} - \hat{q}_{12}^{(5)} \hat{q}_{29}^{(6)} \hat{q}_{91} - \hat{q}_{01} [\hat{q}_{10} \{1 - \hat{q}_{10}^{(6)} \hat{q}_{91} \hat{q}_{10}^{(6)}] + \hat{q}_{29}^{(6)} \hat{q}_{91} \hat{q}_{10}^{(6)} \hat{q}_{1$ 

The steady state availability

$$A_{0} = \lim_{t \to \infty} \left[ A_{0}(t) \right] = \lim_{s \to 0} \left[ s \, \hat{A}_{0}(s) \right] = \lim_{s \to 0} \frac{s \, N_{2}(s)}{D_{2}(s)}$$
Using L' Hospitals rule, we get
$$A_{0} = \lim_{s \to 0} \frac{N_{2}(s) + s \, N_{2}(s)}{D_{2}(s)} = \frac{N_{2}(0)}{D_{2}(0)}$$
(13)

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

$$\lambda_{u(t)} = \int_{0}^{\infty} A_{0}(z) dz \text{ So that } \overline{\lambda_{u}}(s) = \frac{\overline{A_{0}(s)}}{s} = \frac{N_{0}(s)}{sD_{0}(s)}$$
(14)  
The expected down time of the system in (0,t] is

$$\lambda_{\vec{a}}(t) = t - \lambda_{u}(t) \text{ So that } \overline{\lambda_{\vec{a}}}(s) = \frac{1}{s^2} - \overline{\lambda_{u}}(s)$$
(15)

The expected busy period of the server when there is failure due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle and failure due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit respectively in (0,t]  $P_{c}(t) = q_{c}(t)[c]P_{c}(t) + q_{c}(t)[c]P_{c}(t)$ 

$$R_{0}(t) = q_{01}(t)[c]R_{1}(t) + q_{02}(t)[c]R_{2}(t)$$

$$R_{1}(t) = S_{1}(t) + q_{10}(t)[c]R_{0}(t) + q_{12}^{(5)}(t)[c]R_{2}(t) + q_{11}^{(4)}(t)[c]R_{1}(t)$$

$$R_{2}(t) = S_{2}(t) + q_{23}(t)[c]R_{3}(t) + q_{28}^{(7)}(t)R_{8}(t) + q_{29}^{(6)}(t)][c]R_{9}(t)$$

$$R_{3}(t) = S_{3}(t) + q_{30}(t)[c]R_{0}(t)$$

$$R_{8}(t) = S_{8}(t) + q_{82}(t)[c]R_{2}(t)$$

$$R_{9}(t) = S_{9}(t) + q_{91}(t)[c]R_{1}(t)$$
where
$$S_{1}(t) = p G_{1}(t) e^{-\lambda_{1} t} S_{1}(t) = q G_{2}(t) e^{-\lambda_{2} t} \overline{S_{3}(t)} = S_{8}(t) = S_{9}(t) = G_{3}(t)$$
(16-21)

Taking Laplace Transform of eq. (16-21) and solving for  $\overline{R_0}(s)$ 

$$R_{\mathfrak{g}}(\mathfrak{s}) = N_3(\mathfrak{s}) / D_2(\mathfrak{s})$$
(23)

where

In the long run,  $R_0 =$ 

$$\begin{split} \mathbf{N}_{3}(s) &= \hat{\mathbf{q}}_{01} \left[ \hat{S}_{1}(1 - \hat{\mathbf{q}}_{28}^{(7)} \hat{\mathbf{q}}_{82}) + \hat{\mathbf{q}}_{12}^{(5)} \left[ \hat{S}_{2} + \hat{\mathbf{q}}_{23} \hat{S}_{3} + \hat{\mathbf{q}}_{28}^{(7)} (\hat{S}_{8} + \hat{\mathbf{q}}_{29}^{(6)} \hat{S}_{9}) \right] + \hat{\mathbf{q}}_{02} \left[ (\hat{S}_{2} + \hat{\mathbf{q}}_{23} \hat{S}_{3} + \hat{\mathbf{q}}_{28}^{(7)} \hat{S}_{8} + \hat{S}_{9} \hat{\mathbf{q}}_{29}^{(6)} ) (1 - \hat{\mathbf{q}}_{11}^{(4)}) + \hat{S}_{1} \hat{\mathbf{q}}_{29}^{(6)} \hat{\mathbf{q}}_{91} \right] \\ \text{and D}_{2}(s) \text{ is already defined.} \\ \text{(Omitting the arguments s for brevity)} \end{split}$$

 $\frac{N_{\rm s}\left(0\right)}{D_{\rm s}\left(0\right)} \tag{24}$ 

The expected period of the system under failure due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle and failure due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit is

$$\lambda_{PV}(t) = \int_{0}^{\infty} R_{0}(z) dz \text{ So that } \overline{\lambda_{PV}}(s) = \frac{\overline{R}_{0}(s)}{s}$$
The expected number of visits by the repairman Type-I or Type-II for repairing the identical units in (0, t]  

$$H_{0}(t) = Q_{01}(t)[s][1+H_{1}(t)] + Q_{02}(t)[s][1+H_{2}(t)]$$

$$H_{1}(t) = Q_{10}(t)[s]H_{0}(t)] + Q_{12}^{(5)}(t)[s] H_{8}(t) + Q_{11}^{(4)}(t)] [s]H_{1}(t),$$

$$H_{2}(t) = Q_{23}(t)[s]H_{3}(t) + Q_{28}^{(7)}(t) [s] H_{8}(t) + Q_{29}^{(6)}(t)] [c]H_{9}(t)$$

$$H_{3}(t) = Q_{30}(t)[s]H_{0}(t)$$

$$H_{8}(t) = Q_{82}(t)[s]H_{2}(t)$$

$$H_{9}(t) = Q_{91}(t)[s]H_{1}(t)$$
(25-30)

Taking Laplace Transform of eq. (25-30) and solving for  $H_0^{-1}(s)$ 

 $H_{0}^{*}(s) = N_{4}(s) / D_{3}(s)$ (31)  $N_{4}(s) = \{Q_{01}^{*} + Q_{02}^{*}\} [\{1 - Q_{28}^{(7)*} Q_{82}^{*}\} - Q_{12}^{(5)*} Q_{29}^{(6)*} Q_{91}^{*}]$ And  $D_{3}(s) = \{1 - Q_{11}^{(4)*}\} \{1 - Q_{28}^{(7)*} Q_{82}^{*}\} - Q_{12}^{(5)*} Q_{29}^{(6)*} Q_{91}^{*} - Q_{01}^{*}[Q_{10}^{*}\{1 - Q_{28}^{(7)*} Q_{82}^{*}\} + Q_{12}^{(5)*} Q_{23}^{*} Q_{30}^{*}] - Q_{02}^{*} Q_{30}^{*}\{1 - Q_{11}^{(4)*}\} + Q_{29}^{(6)*} Q_{91}^{*} - Q_{11}^{(6)*} Q_{91}^{*} - Q_{01}^{*}[Q_{10}^{*}\{1 - Q_{28}^{(7)*} Q_{82}^{*}\} + Q_{12}^{(5)*} Q_{23}^{*} Q_{30}^{*}] - Q_{02}^{*} Q_{30}^{*}\{1 - Q_{11}^{(4)*}\} + Q_{29}^{(6)*} Q_{91}^{*} - Q_{11}^{(5)*} Q_{29}^{(6)*} Q_{91}^{*} - Q_{01}^{*}[Q_{10}^{*}\{1 - Q_{28}^{(7)*} Q_{82}^{*}\} + Q_{12}^{(5)*} Q_{23}^{*} Q_{30}^{*}] - Q_{02}^{*} Q_{30}^{*}\{1 - Q_{11}^{(4)*}\} + Q_{29}^{(6)*} Q_{91}^{*} - Q_{11}^{(6)*} Q_{91}^{*} - Q_{01}^{*}[Q_{10}^{*}\{1 - Q_{28}^{(7)*} Q_{82}^{*}\} + Q_{12}^{(5)*} Q_{23}^{*} Q_{30}^{*}] - Q_{02}^{*} Q_{30}^{*}\{1 - Q_{11}^{(4)*}\} + Q_{29}^{(6)*} Q_{91}^{*} - Q_{11}^{(6)*} Q_{10}^{*} = Q_{10}^{(6)} Q_{10}^{*} Q_{10}^{*}$  Taking Laplace Transform of eq. (33-38) and solving for  $H_0^*(s)$ 

## **BENEFIT- FUNCTION ANALYSIS**

The Benefit-Function analysis of the system considering mean up-time, expected busy period of the system under failure due to unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle and failure due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit, 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 unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle and failure due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit for repairing the units in (0,t]
- expected number of visits by the repairman Type- I or Type- II for repairing of identical the units in (0,t]
- expected number of visits by the multispecialty repairman Type- III for repairing of identical the units in (0,t]

The expected total cost per unit time in steady state is

$$C = \lim_{t \to \infty} (C(t)/t) = \lim_{s \to 0} (s^2 C(s)) = K_1 A_0 - K_2 R_0 - K_3 H_0 - K_4 W_0$$
  
where

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K<sub>1</sub>: Revenue per unit up-time,

 $K_2$ : Cost per unit time for which the system is busy under repairing,

K3: Cost per visit by the repairman type- I or type- II for units repair,

K4: Cost per visit by the multispecialty repairman Type- III for units repair

# **CONCLUSION**

After studying the system, we have analyzed graphically that when the failure rate unexpected large disturbance at the second stage separation resulting in a sub-orbital flight of the vehicle and failure due to Developmental Flight, payload placed into lower than planned orbit, and did not have sufficient fuel to reach a usable orbit increases, the MTSF, steady state availability decreases and the Profit-function decreased as the failure increases.

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