ITEM	PART NAME
1	MULTIPLE H_2O FEMALE DISCONN
2	SUIT ELEC UMBILICAL
3	MULTIPLE H_2O MALE DISCONN
4	H_2O ΔT TRANSDUCER
5	PUMP MOTOR ASSY
7	CHECK VALVE
11	S/O VALVE
15	FLOW LIMITER
16	H_2O RESERVOIR
17	FILL CONN
18	WATER SUBLIMATOR
19	DRAIN CONN
20	H_2O SEPARATOR, 1ST STAGE
21	TEMP TRANSDUCER
22	LiOH CANISTER
23	OXYGEN BOTTLE
24	O_2 FILL CONN
25	O_2 REG & S/O ASSY
27	PGA PRESS DIFF SWITCH
28	PGA PRESS DIFF TRANS
29	FAN/MOTOR ASSY
30	CHECK VALVE
31	O_2 CONNECTORS
32	POWER SUPPLY
33	CURRENT SENSOR
34	TERMINAL BOX
35	REMOTE CONTROL UNIT
37	COMMUNICATIONS
39	ORIFICE
40	H_2O CONN STOWAGE CAP
41	ANTENNA
42	GAS SEPARATOR
43	O_2 INLET CONN STOWAGE PLATE
44	O_2 OUTLET CONN STOWAGE PLATE
45	PLSS/PGA ELEC UMBILICAL STWG PLT
46	BATT CABLE STOWAGE PLATE
47	PRESSURE PORT
48	S/O VALVE, DOUBLE BANK
49	H_2O SEPARATOR, 2ND STAGE

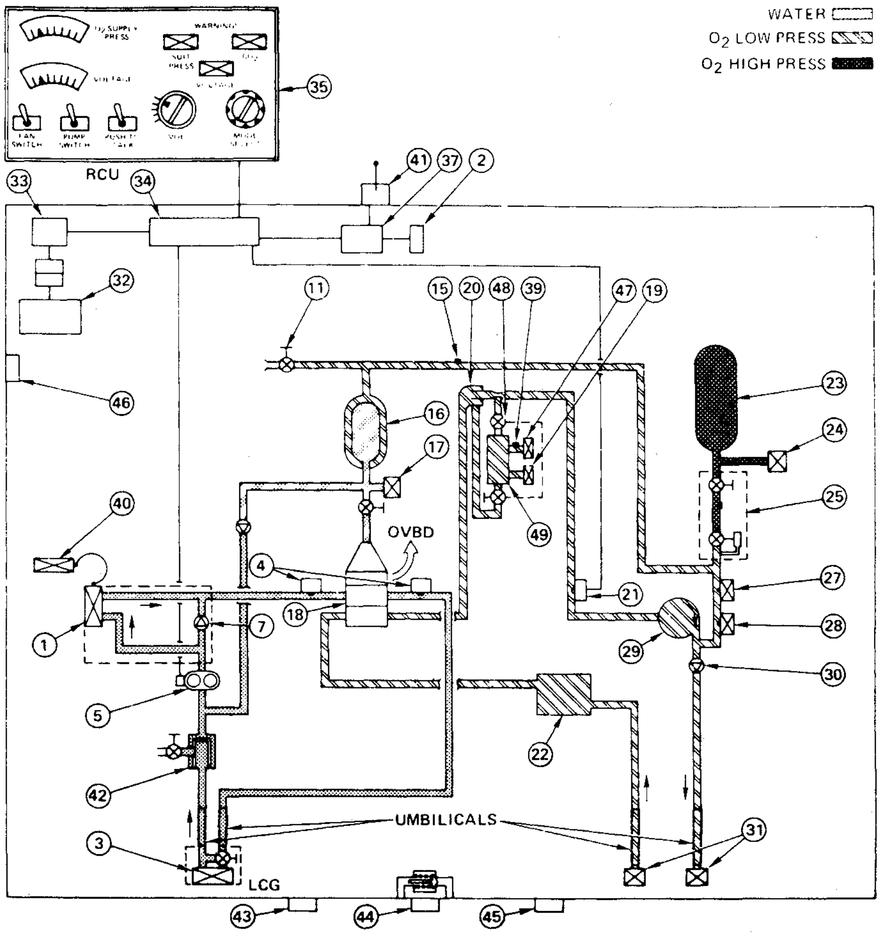

Fig. 4 PLSS schematic (water sublimator option).

The PLSS schematic with the water boiler option is depicted in Fig. 3 and is the same as the flash evaporator system except that the flash evaporator subsystem is replaced with an integral wick-fed water boiler. The sink temperature is controlled by the back pressure control valve which is a temperature sensing device. Notice that full flow of the liquid heat transport loop through the boiler is maintained to allow for cooling of the O_2 ventilation loop during umbilical operation.

The PLSS schematic with the water sublimator option is depicted in Fig. 4 and is the same as the flash evaporator system except that the flash evaporator subsystem is replaced with the water sublimator subsystem. The water reservoir (item 16) is pressurized to 8.0 psia by the O_2 ventilation loop and acts as the accumulator for the liquid heat transport loop as well as supplying expendable water to the sublimator. Again, full flow through the sublimator is maintained to allow for cooling of the O_2 ventilation loop during umbilical operation.

IV. Conclusions

General conclusions emanating from the Shuttle EVA/IVA Support Requirements Study in the area of EVA life support equipment are as follows.

1) The PLSS should be a closed-loop, self-contained system with the capability for liquid-loop umbilical operation.

2) The PLSS and the Emergency Life Support System (ELSS) should be structurally integrated to minimize weight and volume and to eliminate functional interfaces, and thus reduce the operational time required to stow, don/doff, and recharge the equipment.

Time Requirements for Multiple Intersatellite Transfers

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Nomenclature

k = ft/naut mile, constant
N = total number of revolutions required in all transfer ellipses
n = number of revolutions in transfer ellipse
Q = represents result of a calculation
r = radius of circular orbit, naut miles
T = time, days
$\Delta\lambda$ = phase (position) change in a circular orbit, deg
ΔV = change in velocity, fps
τ = period of an orbit, days or sec as required
μ = Earth's gravitational constant, naut miles^3

Subscripts
c = original circular orbit
i = ith transfer ellipse
j = jth transfer ellipse
1 = first transfer
2 = second transfer
3 = third transfer

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Introduction

THERE has recently been considerable interest in space servicing as a means of maintaining a satellite system. When more than one satellite is visited in a single service mission, the intersatellite transfer time(s) [and ΔV requirement(s)] become of interest. A derivation of a simple yet accurate expression for total transfer time for any number of intersatellite transfers is given as follows.

Derivation

Let the period of a circular orbit be τ units of time. Let a phase change be made in the circular orbit of $\Delta\lambda_1$ degrees in n_1 revolutions. A phase advance will be defined as positive and a phase regression as negative.

Each revolution in the phasing ellipse results in a phase change of

$$\Delta\lambda_i = \Delta\lambda_1/n_1 \tag{1}$$

degrees. The period of the ellipse must therefore be

$$\tau_i = \tau\left(1 - \frac{\Delta\lambda_1/n_1}{360}\right) \tag{2}$$

The time required to complete n_1 revolutions and therefore to complete the transfer is

$$T_1 = \tau\left(n_1 - \frac{\Delta\lambda_1}{360}\right) \tag{3}$$

Suppose it is now desired to transfer an additional $\Delta\lambda_2$ degrees in n_2 revolutions. As before,

$$\Delta\lambda_j = \Delta\lambda_2/n_2 \tag{4}$$

$$\tau_j = \tau\left(1 - \frac{\Delta\lambda_2/n_2}{360}\right) \tag{5}$$

$$T_2 = \tau\left(n_2 - \frac{\Delta\lambda_2}{360}\right) \tag{6}$$

The total time to transfer over $\Delta\lambda_1 + \Delta\lambda_2$ is $T_1 + T_2$.

$$T_1 + T_2 = \tau\left(n_1 + n_2 - \frac{\Delta\lambda_1 + \Delta\lambda_2}{360}\right) \tag{7}$$

Equation (7) very strongly implies the result that will be obtained if additional transfers are required. It is a logical step to the general conclusion

$$T = \tau\left(N - \frac{\Delta\lambda}{360}\right) \tag{8}$$

Observations

The general conclusion reached previously in Eq. (8) applies to any number of intersatellite transfers in any circular orbit. It is totally independent of the allocation of the total number of revolutions among the intersatellite transfers. It applies when all transfers are advances, when all transfers are regressions, and when the transfers are both advances, and regressions. Thus, $\Delta\lambda$ is always the *net* phase change. Equation (8) is exact; i.e., no approximations are used in its derivation.

It is to be noted that T contains only intersatellite transfer times. It does not contain rendezvous and dwell times.

Application

One application of Eq. (8) is optimization of intersatellite transfers in space-servicing missions. An example will illustrate its use.

Suppose that four satellites are located in synchronous equatorial orbit with separations of 35°, 150°, and 40° for a total of 225.° Equation (8) becomes

$$T = N - 0.625 \tag{9}$$

sidereal days.† Since three intersatellite transfers are required, the minimum value of N is three. The minimum transfer time is therefore 2.375 sidereal days. The addition of one revolution to *any one* of the three intersatellite transfers lengthens the mission by one sidereal day.

Suppose it is desired to optimize space-servicing payload capability as a function of mission time. This requires a minimization of the total ΔV requirement for the three intersatellite transfers. The ΔV requirement depends upon the number of revolutions required for each individual transfer. Therefore, for a given mission duration and consequently a given value of N, the correct procedure is to allocate N among the three intersatellite transfers in such a way as to minimize ΔV.

A concrete example follows. Suppose that a total transfer time of 11.375 days is considered. N is therefore 12, and N can be split among the three intersatellite transfers in a very large number of ways. It is required to find the optimal split.

A trial-and-success technique, using Eqs. (10–12) for computing the ΔV requirements, produces the following results (see Table 1):

$$\Delta V = 2k\left(\frac{\mu}{r_c}\right)^{1/2}\left|\left(\frac{2Q - r_c}{Q}\right)^{1/2} - 1\right| \tag{10}$$

$$Q = \left(\frac{\tau_i \mu^{1/2}}{2\pi}\right)^{2/3} \tag{11}$$

$$\tau_i = \tau\left(1 - \frac{\Delta\lambda_i/n_i}{360}\right) \tag{12}$$

$$i = 1, 2, 3$$

Table 1 Trial-and-success technique

Trial 1	
$n_1{}^a = 4$	$\Delta V_1 = 168$ fps
$n_2{}^b = 4$	$\Delta V_2 = 783$
$n_3{}^c = 4$	$\Delta V_3 = 192$
$N = 12$	$\Sigma\Delta V = 1143$ fps
Trial 2	
$n_1 = 4$	$\Delta V_1 = 168$ fps
$n_2 = 5$	$\Delta V_2 = 612$
$n_3 = 3$	$\Delta V_3 = 259$
$N = 12$	$\Sigma\Delta V = 1039$ fps
⋮	
Trial q	
$n_1 = 3$	$\Delta V_1 = 225$ fps
$n_2 = 6$	$\Delta V_2 = 502$
$n_3 = 3$	$\Delta V_3 = 259$
$N = 12$	$\Sigma\Delta V = 986$ fps

[a] n_1 = number of revolutions in 1st transfer (satellite 1 to satellite 2).
[b] n_2 = number of revolutions in 2nd transfer (satellite 2 to satellite 3).
[c] n_3 = number of revolutions in 3rd transfer (satellite 3 to satellite 4).

Trial q produces the least total ΔV and is therefore the optimal case. The optimal number of revolutions for each transfer is therefore as shown in Trial q of Table 1.

† A sidereal day is the time required by the Earth to rotate 360°. It is 23.93 hr in length.