SmallSats Rational Design

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Minisatellite, 100-180 kilograms

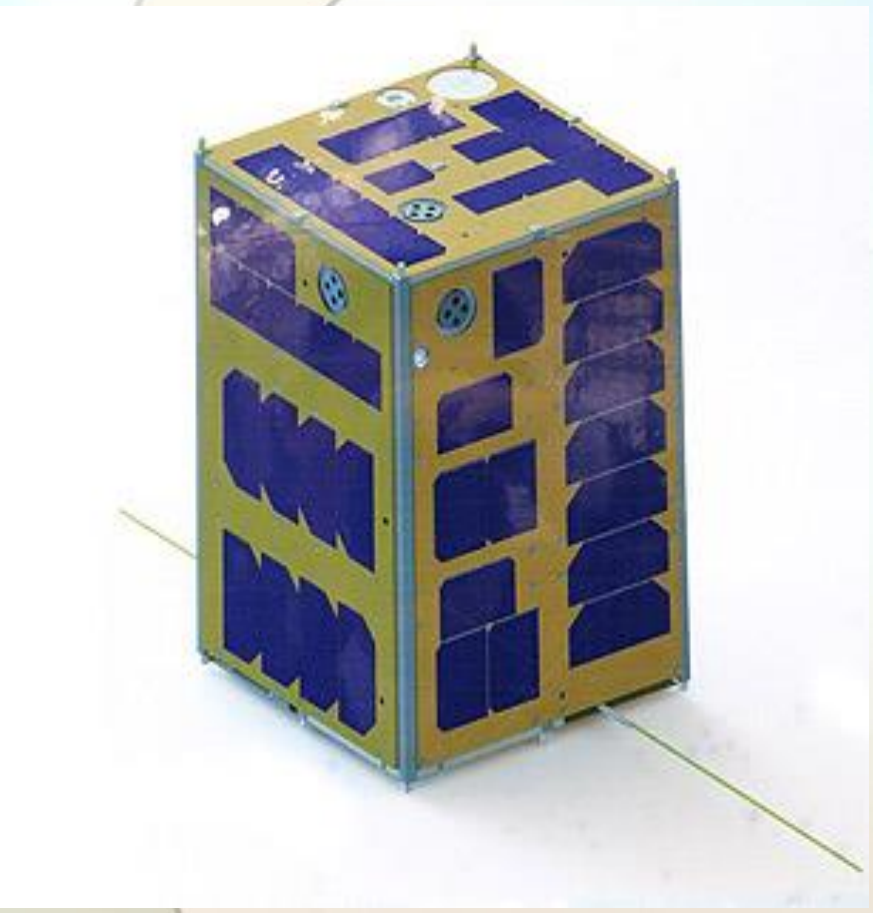
Microsatellite, 10-100 kilograms

Nanosatellite, 1-10 kilograms

Picosatellite, 0.01-1 kilograms

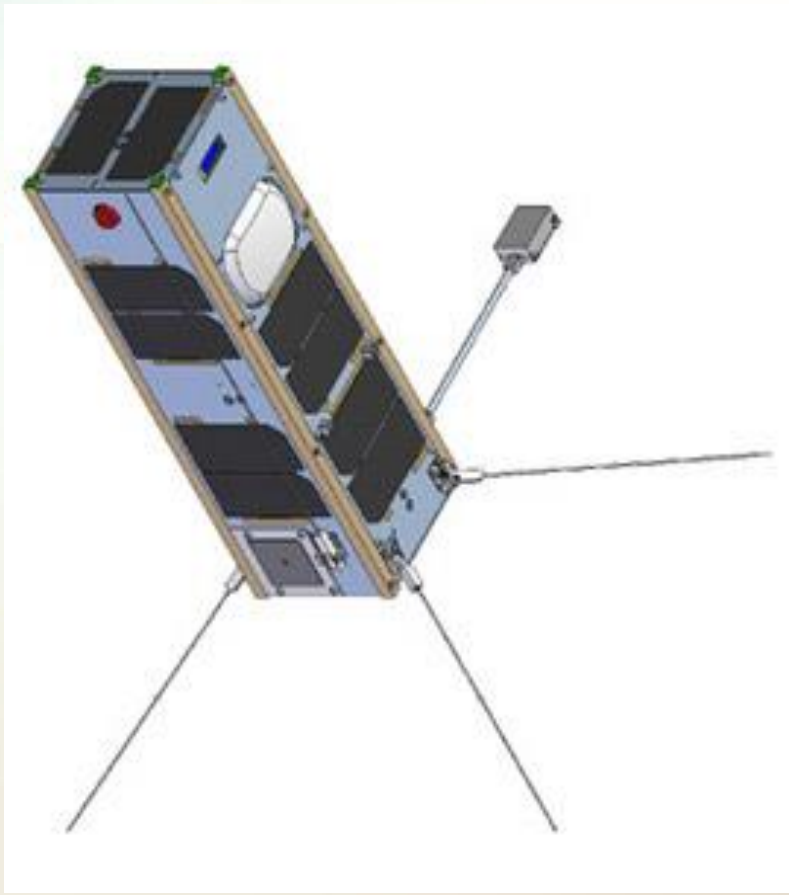
Femtosatellite, 0.001-0.01 kilograms

SmallSats



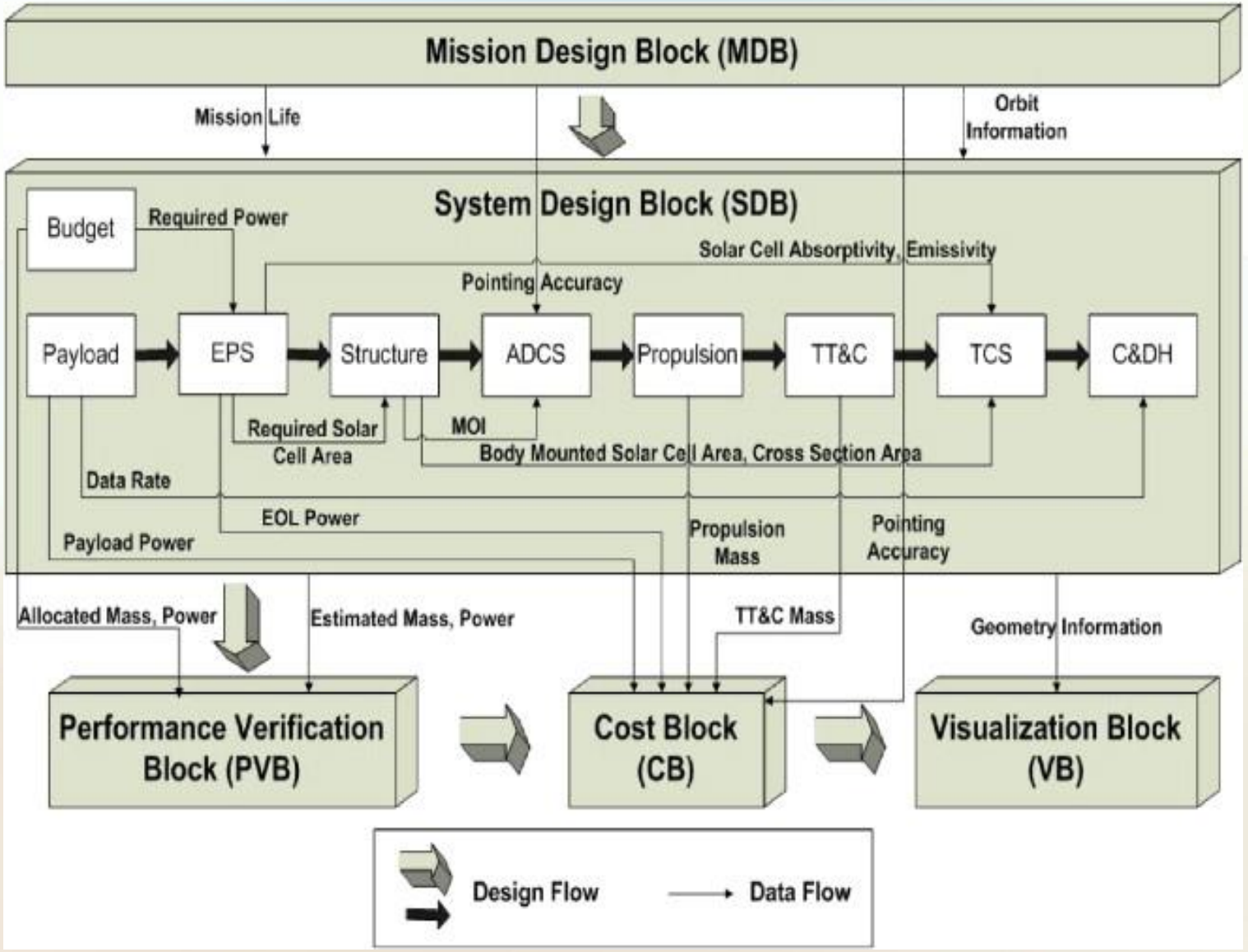
12U CubeSat (Aoxiang Zhixing)

6U (1×6U) CubeSat (ALTAIR 1)

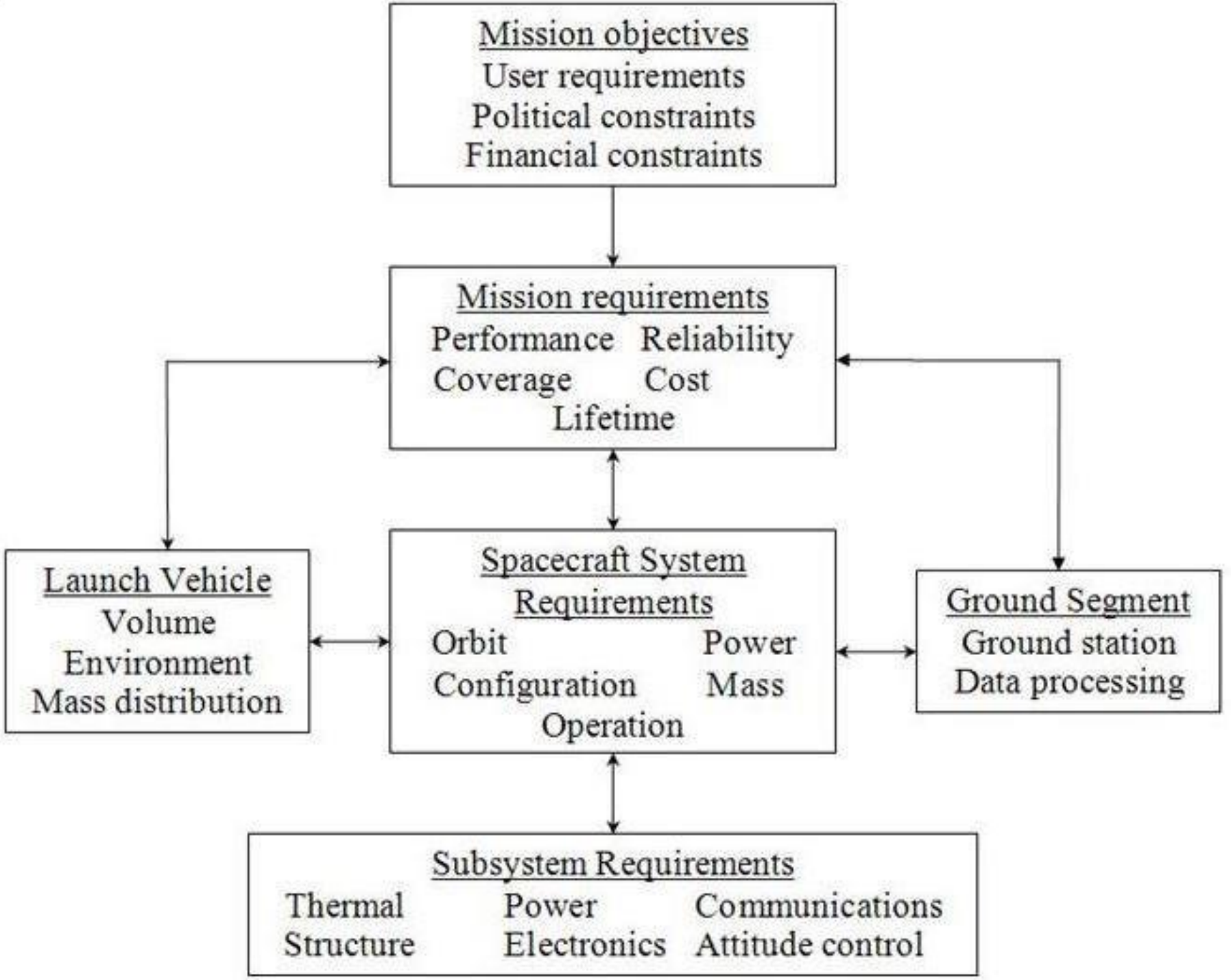


3U CubeSat (CanX 2) [UTIAS]

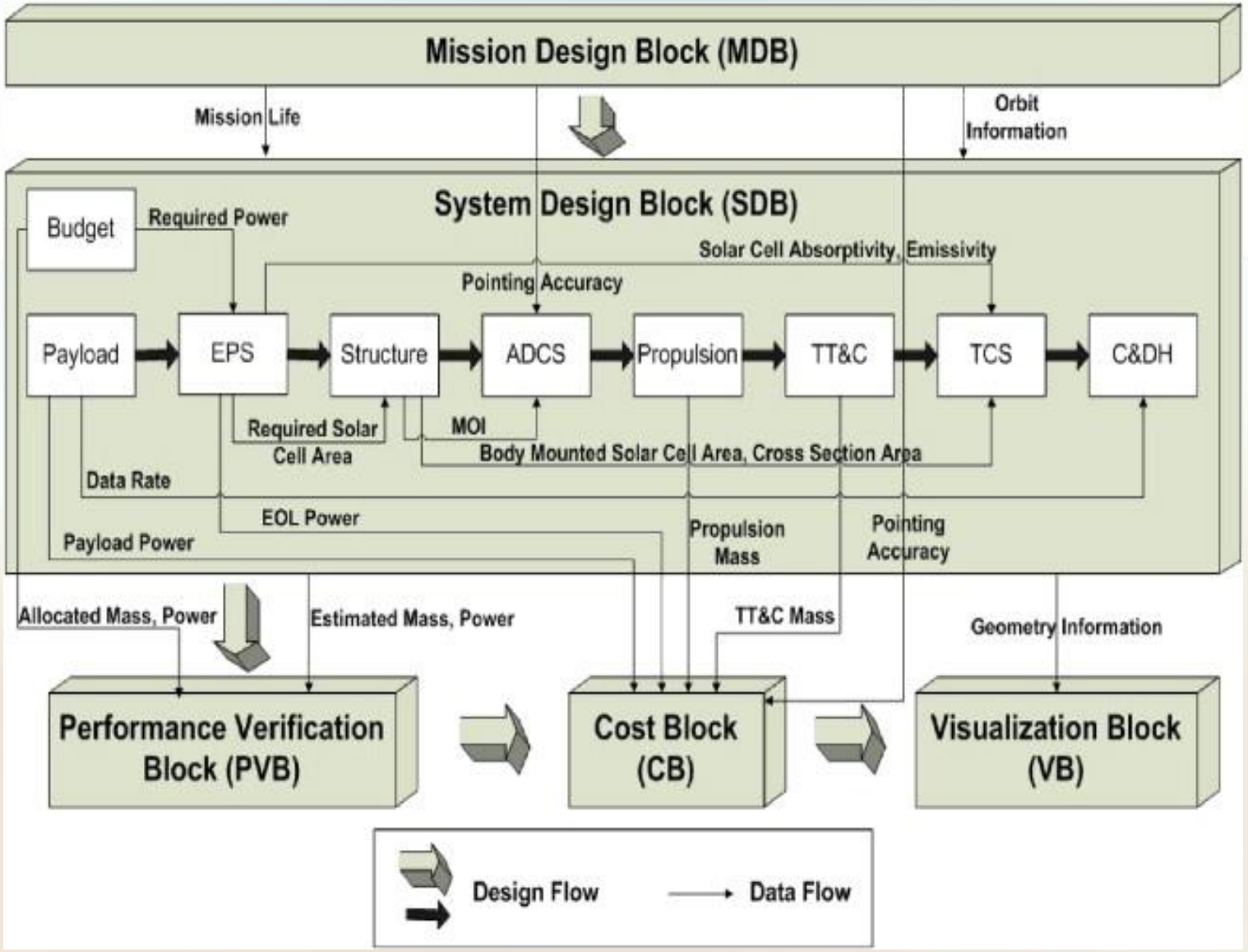
Concept of the Design Process



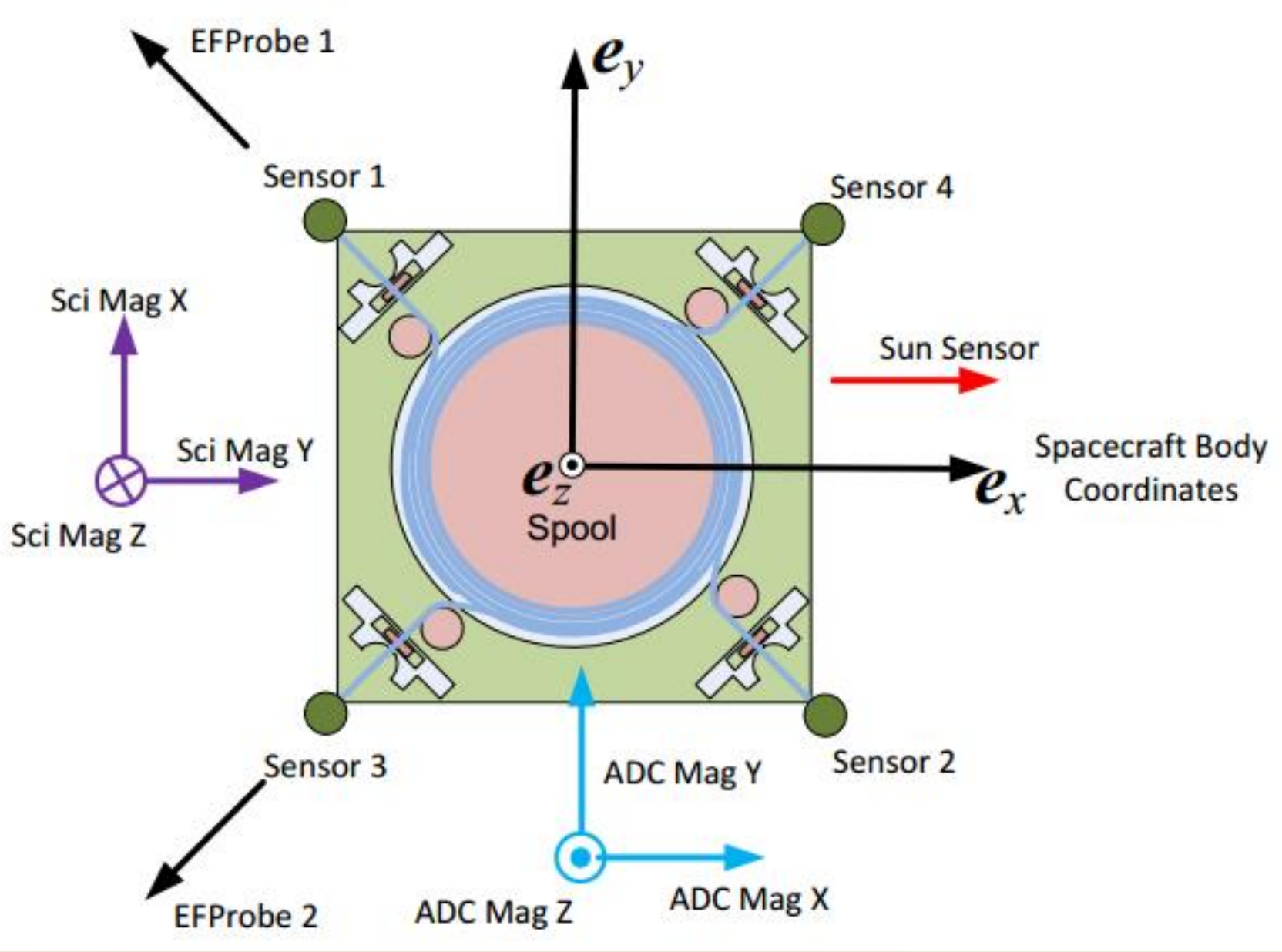
System Engineering Design Tool


Mission objectives
User requirements
Political constraints
Financial constraints
Mission requirements
Performance Reliability
Coverage Cost
Lifetime
Launch Vehicle
Volume
Environment
Mass distribution
Spacecraft System Requirements
Orbit Power
Configuration Mass
Operation
Ground Segment
Ground station
Data processing
Subsystem Requirements
Thermal Power Communications
Structure Electronics Attitude control

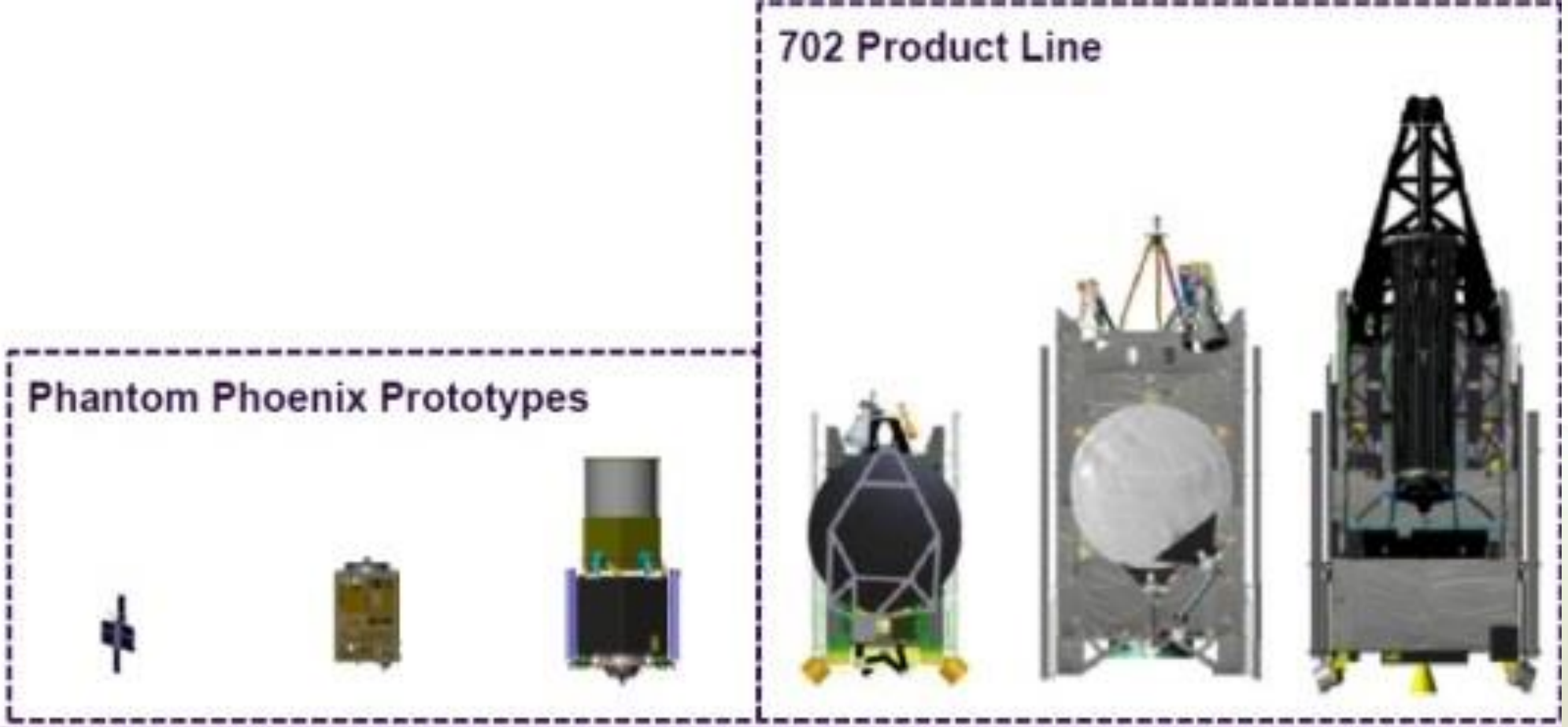
Physical Relationships in the Design Process



System Engineering Design Tool



Dynamic Ionosphere Experiment (DICE) sensor map indicates the relative geometry, based on the spacecraft body coordinates

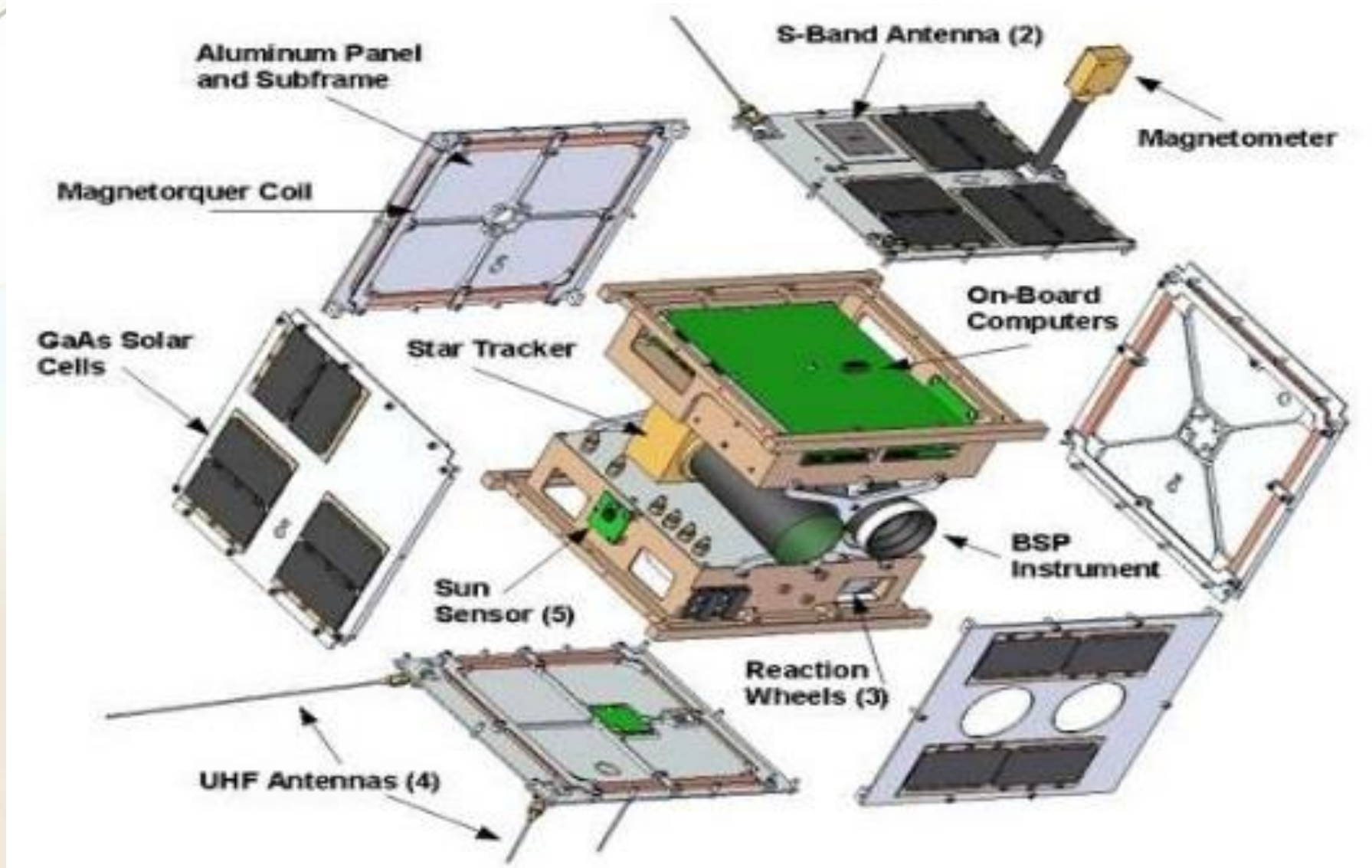


Vehicle	Phoenix Nano	Phoenix ESPA	Phoenix	702SP	702MP	702HP
Payload Power (Cont./Peak)	36W /70W	90W /135 W	280W – 700+W	3.5kW – 7.5 kW	6.0kW – 12 kW	8kw – 12+kW
Total SV Mass	4 – 10 kg	180 kg	500 – 1000 kg	1500-2000 kg	5800-6100 kg	5400-5900 kg
Design Life	1 year	1-5 years	7+ years	15+ years	15+ years	15+ years

Boeing Designs New SmallSat Family

Satellite Comparison (Deep Space Industries)

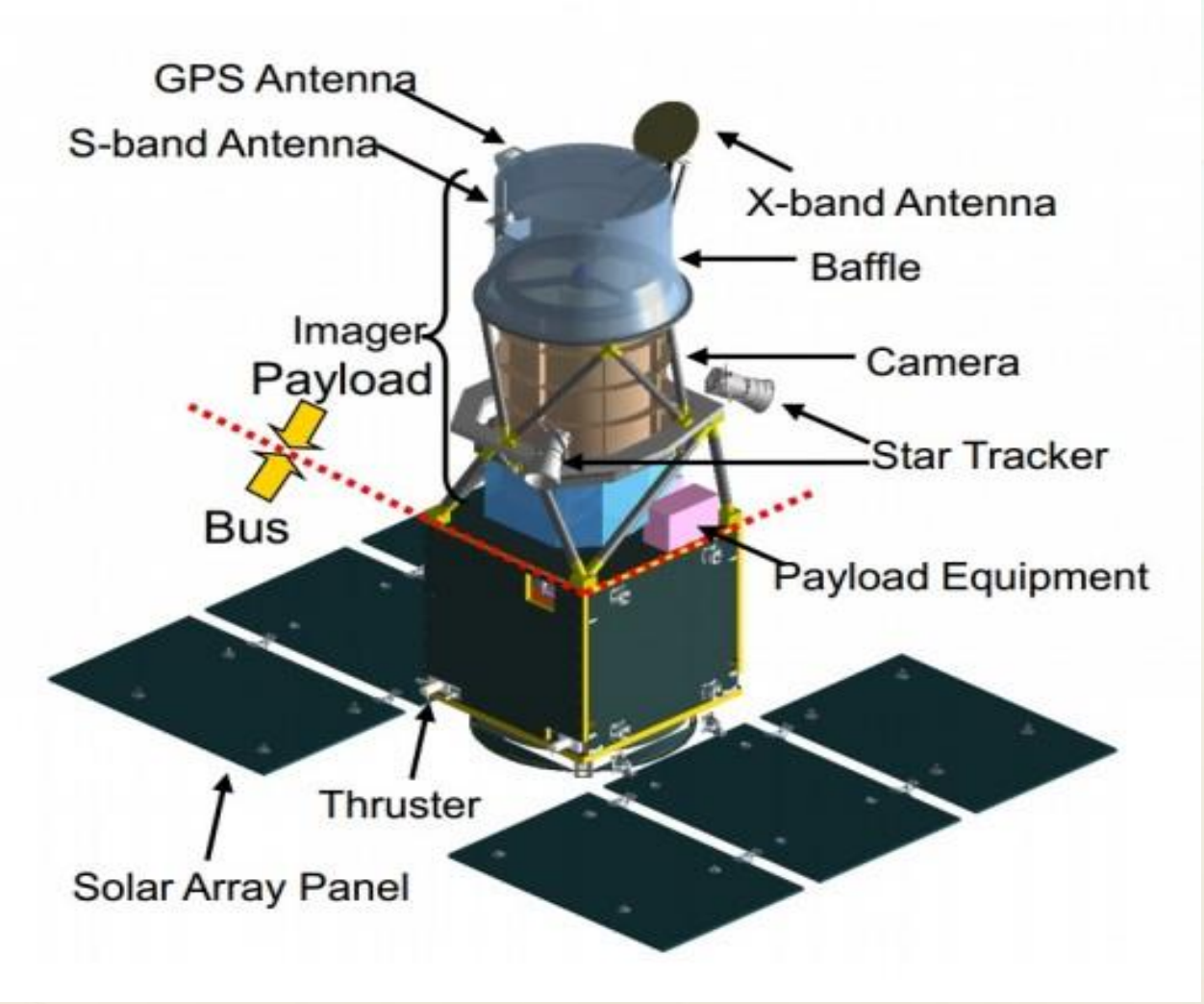
$$M_{Sc} = M_0 - M_{SS} \qquad (1)$$



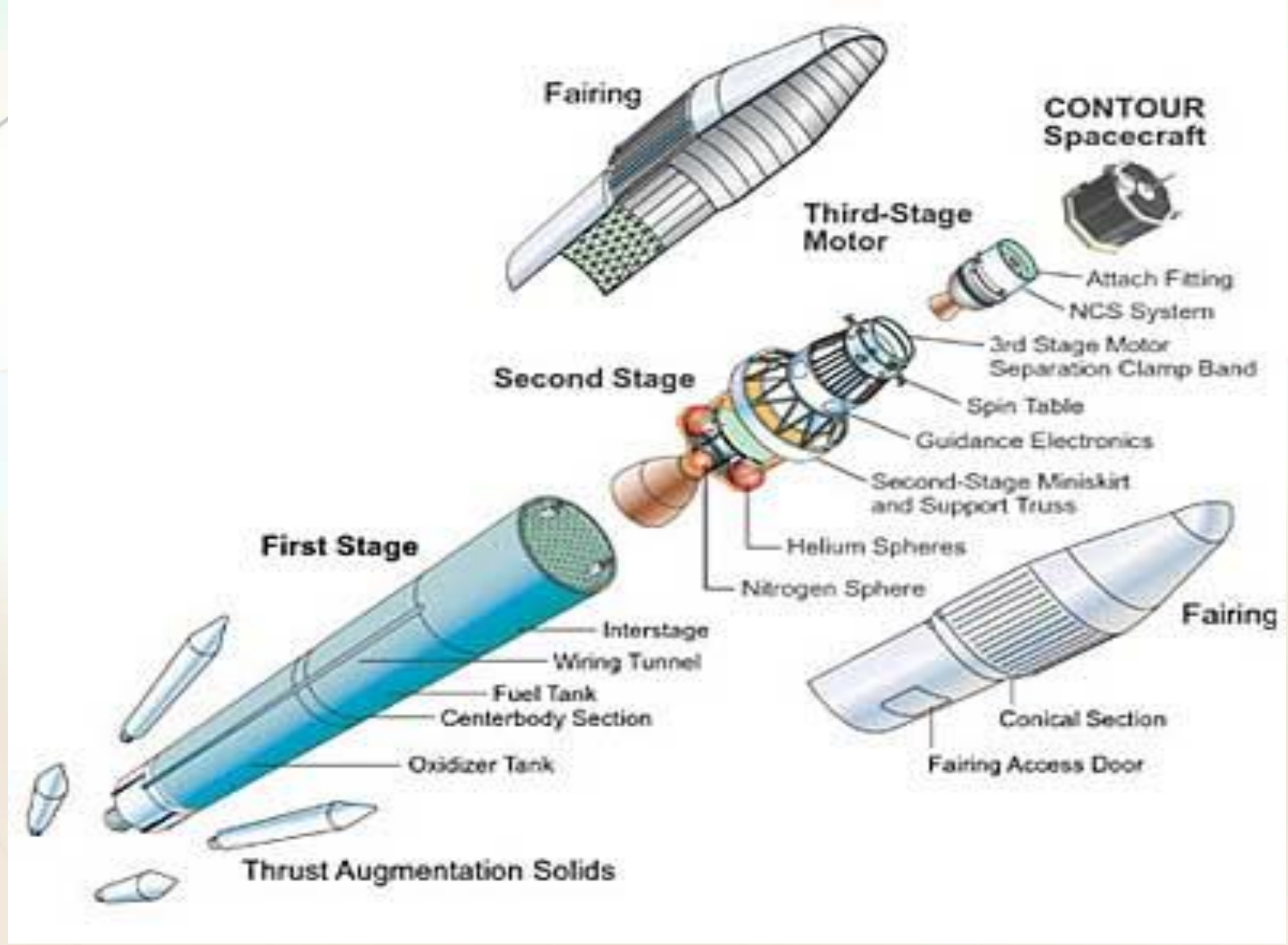
Basic Components of Small Satellite

$$M_{Sc} + f_{SS} M_{Sc} = M_0 - M_{Sc}^0, \quad (2)$$

$$M_{Sc} = F(M_0, M_{SS}^0) \quad (3)$$



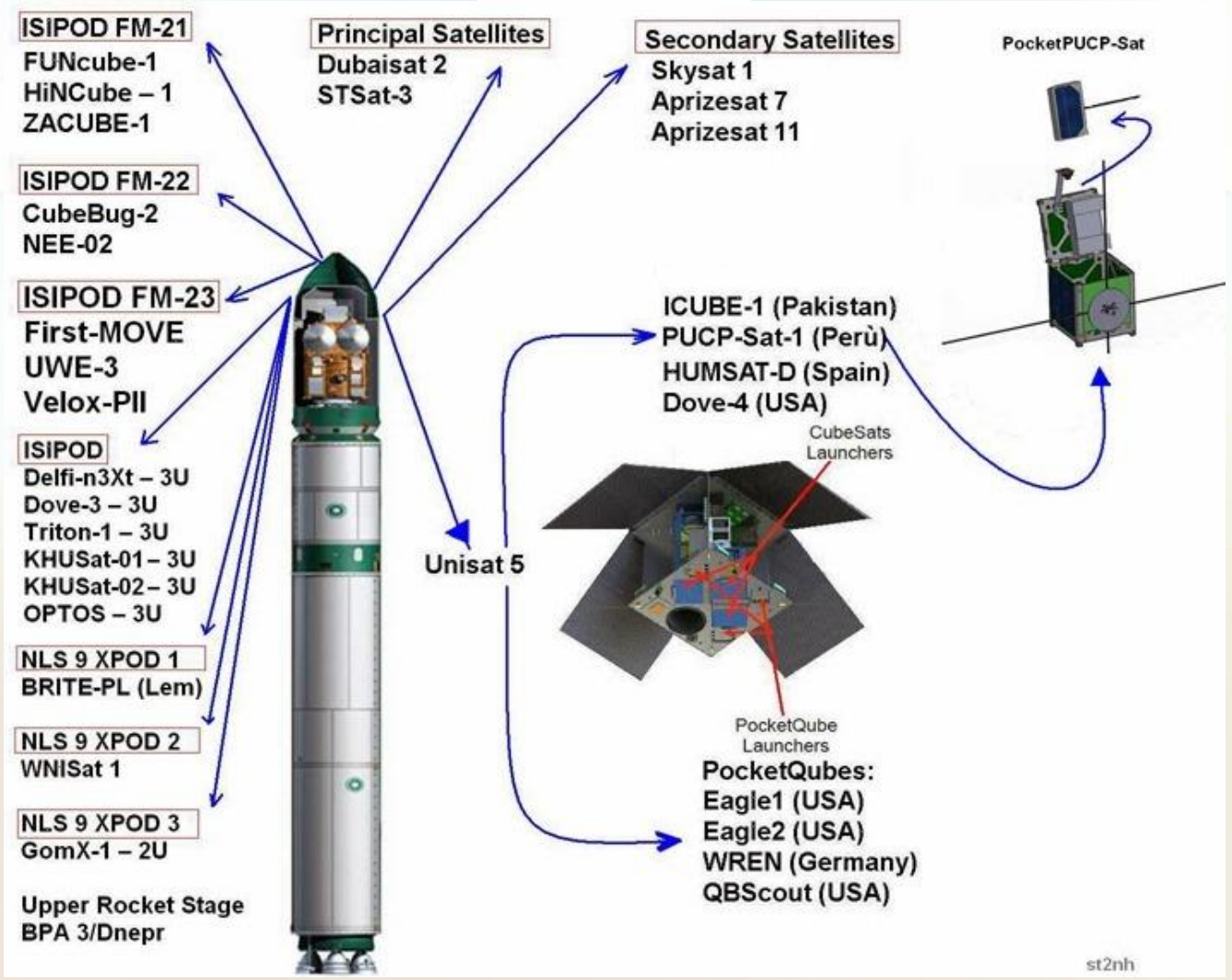
Satellite ASNARO-1



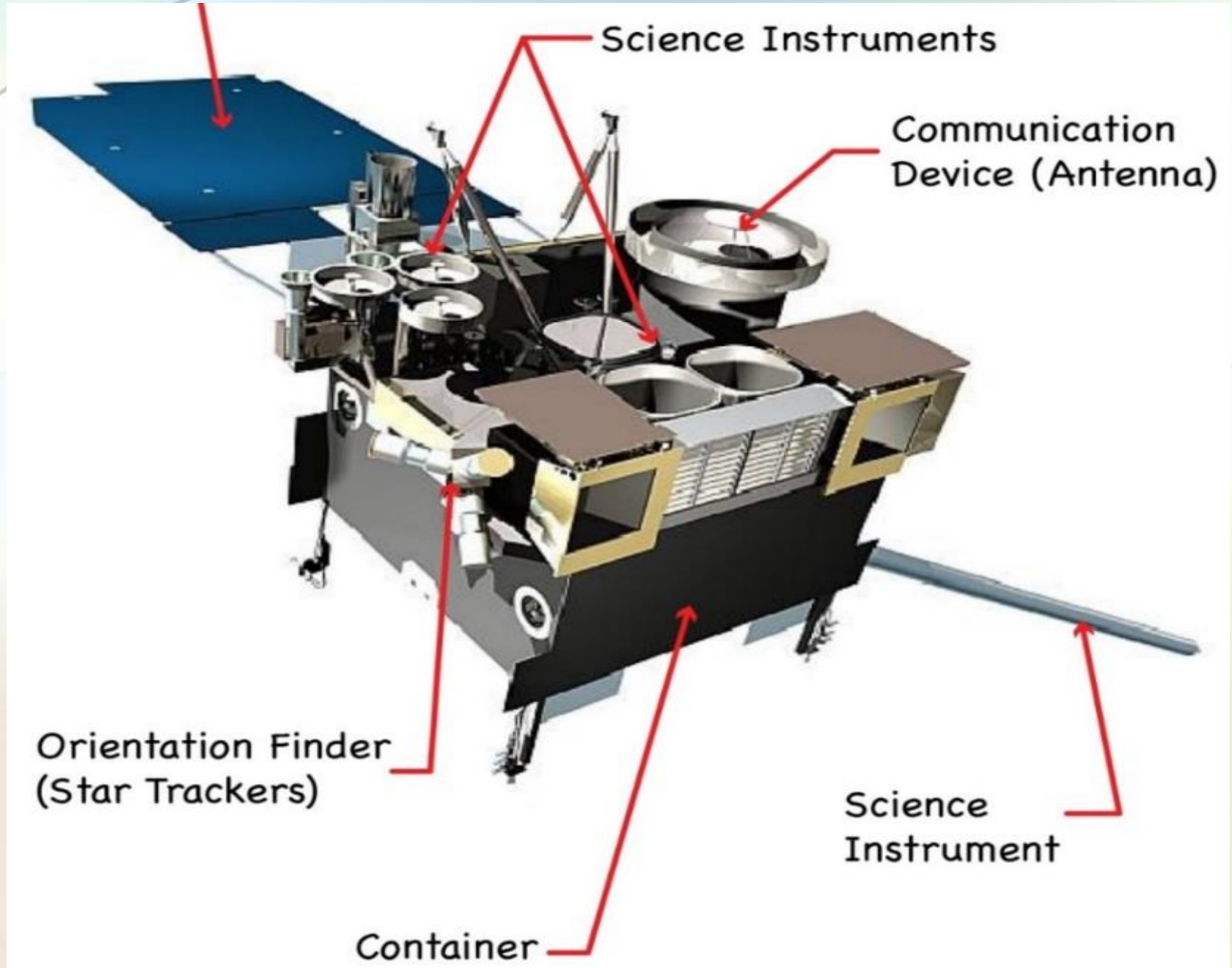
SmallSat Position on a Launch Vehicle

$$B = B\left[\left(C_{m,n}\right),\left(T_i\right),\left(P_j\right),t_0\right] \tag{4}$$

$$B \geq B_0 .$$



Dnepr Launcher Satellites (Ukraine)



SmallSat Design Solution

$$\Phi_r\left[\left(C_{m,n}\right),\left(T_i\right),\left(P_j\right)\right]\begin{cases}=0,\\ \geq 0,\end{cases} \tag{5}$$

$$N_\Sigma = \sum_{m=1}^{M} N_m + I + J \tag{6}$$

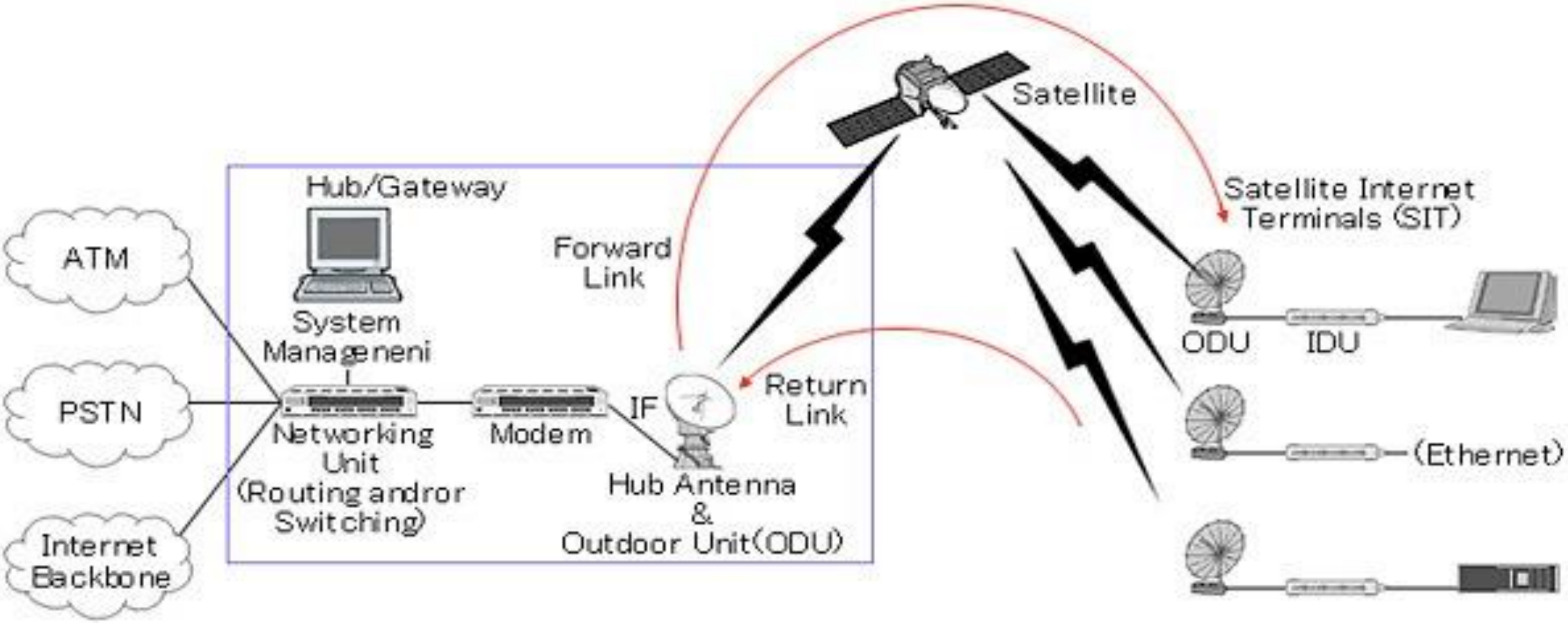
$$K = K\left[\left(C_{m,n}\right),\left(T_i\right),\left(P_j\right)\right] \tag{7}$$

Rational Design Algorithm Version

$$\Phi_r\left[\left(C_{m,n}\right),\left(T_i\right),\left(P_j\right)\right]\begin{cases}=0,\\ \geq 0,\end{cases} \tag{5}$$

$$N_\Sigma = \sum_{m=1}^{M} N_m + I + J \tag{6}$$

$$M_0 = M_{0_{\max}}\left(1 - \frac{\Delta M}{M_{0_{\max}}}\right)$$



SmallSat Data Process Flow

Rational Design Algorithm Version

$$\Phi_r\left[\left(C_{m,n}\right),\left(T_i\right),\left(P_j\right)\right]\begin{cases}=0,\\ \geq 0,\end{cases} \tag{5}$$

$$N_\Sigma = \sum_{m=1}^{M} N_m + I + J \tag{6}$$

$$\left[C'_{m,n}, C''_{m,n}\right], \left[P'_j, P''_j\right] \tag{8}$$

$$K(x_1, x_2, \ldots, x_{N_\Sigma}) \tag{9}$$

$$\Phi_r(x_1, x_2, \ldots, x_{N_\Sigma}) = 0, \tag{10}$$

$$\overline{\Phi} = K + \sum_{r=1}^{R} \lambda_r \Phi_r. \tag{11}$$

$$\frac{\partial \overline{\Phi}}{\partial x_k} = 0, k = 1,2,\ldots, N_\Sigma \tag{12}$$

$$\left.\begin{aligned} &\frac{\partial \Phi_1}{\partial x_1}\Delta x_1 + \ldots + \frac{\partial \Phi_1}{\partial x_{N_\Sigma}}\Delta x_{N_\Sigma} = 0, \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ &\frac{\partial \Phi_R}{\partial x_1}\Delta x_1 + \ldots + \frac{\partial \Phi_R}{\partial x_{N_\Sigma}}\Delta x_{N_\Sigma} = 0. \end{aligned}\right\} \tag{13}$$

$$\Delta K = \sum_{l=1}^{N_\Sigma - R} e_l \Delta x_l. \tag{14}$$