Space Station Reference Coordinate Systems

International Space Station Program

Revision F

26 October 2001

Russian Space Agency

agenzia spaziale italiana
(Italian Space Agency)

esa
european space agency

NASDA
National Space Development Agency of Japan

Canadian Space Agency
Agence spatiale canadienne

National Aeronautics and Space Administration
International Space Station Program
Johnson Space Center
Houston, Texas

REVISION AND HISTORY PAGE

REV.	DESCRIPTION	PUB. DATE
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F	Revision F Incorporates SSCN 003299. The following DCN has been cancelled. The content of the SSCNs authorizing release of the DCN has been incorporated into Revision F. DCN 003 (SSCN 000256) (Administrative Cancel)	

PREFACE

The purpose of this document is to establish a set of coordinate systems to be used when reporting data between the Space Station Program Participants (SSPP).

This document contains figures defining configuration dependent, configuration independent, articulating, viewing, unpressurized, translating, pressurized, and transverse boom frame references frames. In addition, appendixes are included with abbreviations and acronyms, a glossary, subscript designations, and reference documents.

The contents of this document are intended to be consistent with the tasks and products to be prepared by Space Station Program (SSP) participants as defined in SSP 41000, System Specification for Space Station. The Space Station Reference Coordinate Systems shall be implemented on all new SSP contractual and internal activities and shall be included in any existing contracts through contract changes. This document is under the control of the Space Station Control Board, and any changes or revisions will be approved by the Program Manager.

INTERNATIONAL SPACE STATION PROGRAM

SPACE STATION REFERENCE COORDINATE SYSTEMS

26 OCTOBER 2001

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INTERNATIONAL SPACE STATION ALPHA PROGRAM

SPACE STATION REFERENCE COORDINATE SYSTEMS

26 OCTOBER 2001

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INTERNATIONAL SPACE STATION ALPHA PROGRAM

SPACE STATION REFERENCE COORDINATE SYSTEMS

26 OCTOBER 2001

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For NASA DATE

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For CSA DATE

Agreed to in principal subject to completion of detailed review by CSA and its contractor.

NASA/ESA

INTERNATIONAL SPACE STATION ALPHA PROGRAM

SPACE STATION REFERENCE COORDINATE SYSTEMS

26 OCTOBER 2001

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For NASA DATE

/s/ Helmut Heusmann 3/23/94

For ESA DATE

Pending definition of AR5XATV launched APM coordinate system origin, ref. ESA Letter MES/007/94/HH/em, dated 23 Feb, 1994.
Note: Document not called up as applicable to ESA.

NASA/NASDA

INTERNATIONAL SPACE STATION ALPHA PROGRAM

SPACE STATION REFERENCE COORDINATE SYSTEMS

26 OCTOBER 2001

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For NASA DATE

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Agreed to in principal subject to completion of detailed review by NASDA.

NASA/RSA

INTERNATIONAL SPACE STATION ALPHA PROGRAM

SPACE STATION REFERENCE COORDINATE SYSTEMS

26 OCTOBER 2001

/s/ Dale Thomas 3/11/94

For NASA DATE

For RSA DATE

SPACE STATION PROGRAM OFFICE

SPACE STATION REFERENCE COORDINATE SYSTEMS

LIST OF CHANGES

26 OCTOBER 2001

All changes to paragraphs, tables, and figures in this document are shown below:

SSCBD	ENTRY DATE	CHANGE	PARAGRAPH
3299	10/26/01	1.3	PRECEDENCE
		5.0	ARTICULATING AND TRANSVERSE BOOM REFERENCE FRAMES
		8.0	TRANSLATING REFERENCE FRAMES
		9.0	PRESSURIZED MODULE REFERENCE FRAMES
			TABLE(S)
	10/26/01		NONE.
			FIGURE(S)
3299	10/26/01		ALL FIGURES WERE CHANGED FOR UPDATE TO CORRECT FORMAT. ADDITIONAL CHANGES WERE MADE TO THE FOLLOWING:
		3.0–15	RUSSIA ORBITAL COORDINATES SYSTEM
		3.0–16	RSO: RUSSIAN SUN EQUILIBRIUM ATTITUDE COORDINATES SYSTEM
		4.0–2	SPACE STATION REFERENCE COORDINATE SYSTEM
		4.0–4	RSA ANALYSIS COORDINATE SYSTEM
		4.0–9	SOYUZ TM TRANSPORT MANNED VEHICLE COORDINATE SYSTEM
		4.0–10	PROGRESS–M TRANSPORT CARGO VEHICLE COORDINATE SYSTEM
		4.0–12	AUTOMATED TRANSFER VEHICLE COORDINATE SYSTEM
		4.0–13	H–II TRANSFER VEHICLE COORDINATE SYSTEM, MECHANICAL DESIGN REFERENCE

LIST OF CHANGES – Continued

3299 – contd.	10/26/01	4.0–14	H–II TRANSFER VEHICLE COORDINATE SYSTEM, ATTITUDE REFERENCE
		5.0–1	STARBOARD SOLAR POWER MODULE COORDINATE SYSTEM
		5.0–2	INTEGRATED TRUSS SEGMENT S4 COORDINATE SYSTEM
		5.0–3	INTEGRATED TRUSS SEGMENT S5 COORDINATE SYSTEM
		5.0–4	INTEGRATED TRUSS SEGMENT S6 COORDINATE SYSTEM
		5.0–5	PORT SOLAR POWER MODULE COORDINATE SYSTEM
		5.0–6	INTEGRATED TRUSS SEGMENT P4 COORDINATE SYSTEM
		5.0–7	INTEGRATED TRUSS SEGMENT P5 COORDINATE SYSTEM
		5.0–8	INTEGRATED TRUSS SEGMENT P6 COORDINATE SYSTEM
		5.0–9	SOLAR ARRAY WING COORDINATE SYSTEM
		5.0–10	THERMAL CONTROL SYSTEM RADIATOR COORDINATE SYSTEM
		5.0–11	INTEGRATED TRUSS SEGMENT Z1 COORDINATE SYSTEM
		5.0–12	INTEGRATED TRUSS SEGMENT S0 COORDINATE SYSTEM
		5.0–13	INTEGRATED TRUSS SEGMENT S1 COORDINATE SYSTEM
		5.0–14	INTEGRATED TRUSS SEGMENT S3 COORDINATE SYSTEM
		5.0–15	INTEGRATED TRUSS SEGMENT P1 COORDINATE SYSTEM
		5.0–16	INTEGRATED TRUSS SEGMENT P3 COORDINATE SYSTEM
		5.0–17	FGB ARRAYS COORDINATE SYSTEM

LIST OF CHANGES – Continued

3299 – contd.	10/26/01	5.0–18	SERVICE MODULE ARRAYS COORDINATE SYSTEM
		5.0–19	SCIENCE POWER PLATFORM COORDINATE SYSTEM
		5.0–20	SCIENCE POWER PLATFORM RADIATOR COORDINATE SYSTEM
		5.0–21	SCIENCE POWER PLATFORM ARRAYS COORDINATE SYSTEM
		6.0–1	TRACKING AND DATA RELAY SATELLITE SYSTEM (KU–BAND) COORDINATE SYSTEM
		6.0–6	EARLY AMMONIA SERVICER COORDINATE STSTEM
		6.0–7	RACK COORDINATE SYSTEM
		6.0–8	O2/N2 HIGH PRESSURE GAS TANK COORDINATE SYSTEM
		6.0–9	SOLAR ARAY ORU COORDINATE SYSTEM
		6.0–10	PUMP MODULE ASSEMBLY ORU COORDINATE SYSTEM
		6.0–11	S1 GRAPPLE BAR ORU COORDINATE SYSTEM
		6.0–12	RADIATOR ORU COORDINATE SYSTEM
		6.0–13	THERMAL RADIATOR ROTARY JOINT ORU COORDINATE SYSTEM
		6.0–14	MAST CANISTER ORU COORDINATE SYSTEM
		7.0–1	SPACELAB PALLET COORDINATE SYSTEM
		7.0–3	EXTERNAL STOWAGE PLATFORM – 2
		8.0–1	CREW AND EQUIPMENT TRANSLATIONAL AID COORDINATE SYSTEM
		8.0–3	MOBILE TRANSPORTER COORDINATE SYSTEM

LIST OF CHANGES – Continued

3299 – contd.	10/26/01	8.0–4	MOBILE SERVICING CENTRE BASE SYSTEM COORDINATE SYSTEM
		8.0–6	DELETED
		8.0–8	JEM – REMOTE MANIPULATOR SYSTEM COORDINATE SYSTEM
		9.0–1	UNITED STATES LABORATORY MODULE COORDINATE SYSTEM
		9.0–2	UNITED STATES HABITATION MODULE COORDINATE SYSTEM
		9.0–3	MINI PRESSURIZED LOGISTICS MODULE COORDINATE SYSTEM
		9.0–4	JOINT AIRLOCK COORDINATE SYSTEM
		9.0–5	CUPOLA COORDINATE SYSTEM
		9.0–6	RESOURCE NODE 1 COORDINATE SYSTEM
		9.0–7	RESOURCE NODE 2 COORDINATE SYSTEM
		9.0–8	RESOURCE NODE 3 COORDINATE SYSTEM
		9.0–9	CENTRIFUGE ACCOMMODATION MODULE COORDINATE SYSTEM
		9.0–10	JAPANESE EXPERIMENT MODULE (JEM) — PRESSURIZED MODULE (PM) COORDINATE SYSTEM
		9.0–11	JAPANESE EXPERIMENT MODULE EXPERIMENTAL LOGISTICS MODULE PRESSURIZED SECTION COORDINATE SYSTEM
		9.0–12	JAPANESE EXPERIMENT MODULE — EXPERIMENTAL LOGISTICS MODULE EXPOSED SECTION COORDINATE SYSTEM
		9.0–13	JAPANESE EXPERIMENT MODULE EXPOSED FACILITY COORDINATE SYSTEM
		9.0–15	PRESSURIZED MATING ADAPTER–1 COORDINATE SYSTEM

LIST OF CHANGES – Continued

3299 – contd.	10/26/01	9.0–16	PRESSURIZED MATING ADAPTER–2 COORDINATE SYSTEM
		9.0–17	PRESSURIZED MATING ADAPTER–3 COORDINATE SYSTEM
		9.0–18	FGB CARGO BLOC COORDINATE SYSTEM
		9.0–19	SERVICE MODULE (SM) COORDINATE SYSTEM
		9.0–20	DOCKING COMPARTMENT – 1 COORDINATE SYSTEM
		9.0–21	DOCKING COMPARTMENT – 2 COORDINATE SYSTEM
		9.0–22	DELETED
		9.0–23	DELETED
		9.0–24	UNIVERSAL DOCKING MODULE COORDINATE SYSTEM
		9.0–27	RESEARCH MODULE –1 COORDINATE SYSTEM
		9.0–28	RESEARCH MODULE –2 COORDINATE SYSTEM
			APPENDIX
3299	10/26/01		APPENDIX C – SUBSCRIPT DESIGNATIONS
			APPENDIX E – ISS RUSSIAN SEGMENT

TABLE OF CONTENTS

APPENDIXES

FIGURES

TABLE OF CONTENTS – Continued

TABLE OF CONTENTS – Continued

TABLE OF CONTENTS – Continued

TABLE OF CONTENTS – Continued

1.0 INTRODUCTION

This document contains the definitions of the various coordinate systems used throughout the Space Station Program.

1.1 PURPOSE

The purpose of this document is to establish a set of coordinate systems to be used when reporting data between the Space Station Program Participants (SSPP).

1.2 SCOPE

The scope of this document does not extend beyond the realm of communication of data between the SSPPs. Analyses software, preferred conventions, on–orbit operations, on–orbit location coding and internal reports can contain data in whatever coordinate system deemed appropriate.

1.3 PRECEDENCE

In the event of a conflict between this document and any previous versions of SSP 30219, Space Station Reference Coordinate Systems, this document takes precedence. In the case of a conflict between this document and SSP 41000, System Specification for the Space Station; SSP 41000 takes precedence. In the event of a conflict between this document and any released Space Station engineering drawing or ICD, the released engineering drawing or ICD takes precedence.

1.4 DELEGATION OF AUTHORITY

The responsibility of assuring the definition, control, and implementation of the coordinate systems defined in this document is vested with the NASA Space Station Program Office, ASI, CSA, ESA, NASDA, and RSA.

2.0 APPLICABLE DOCUMENTS

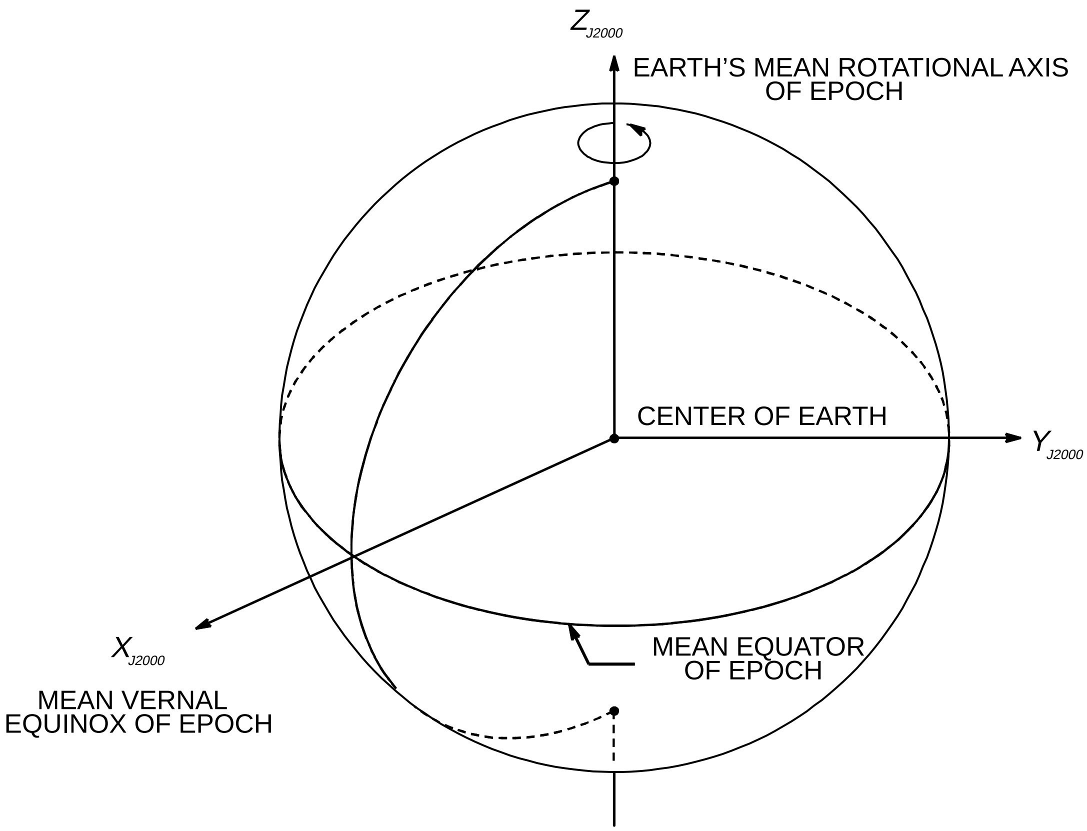
The following documents of the date and issue shown are applicable to the extent specified herein. Inclusion of applicable documents herein does not in any way supersede the order of precedence specified in paragraph 1.3. The references show where each applicable document is cited in this document.

DOCUMENT NO.	TITLE

None

3.0 CONFIGURATION INDEPENDENT REFERENCE FRAMES

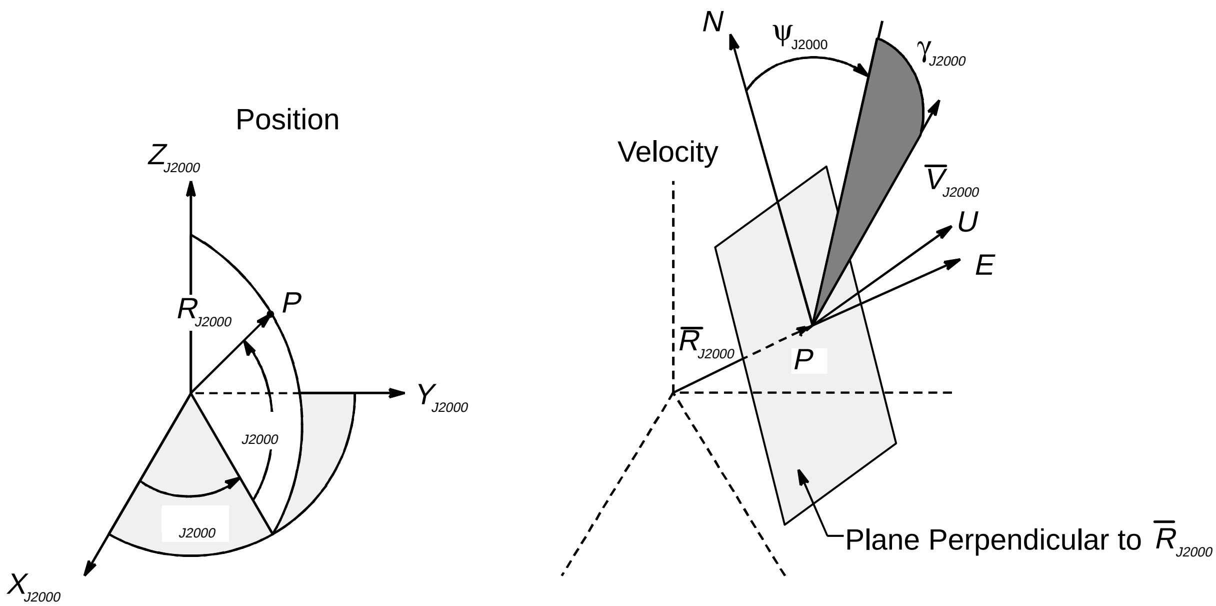
The coordinate systems outlined in this chapter are independent of the Space Station configuration. These coordinates systems are mostly global (with the origin at the center of the earth) in nature and can be used for any spacecraft orbiting the earth.



NAME:	J2000, Mean of 2000, Cartesian Coordinate System*
ORIGIN:	The center of the Earth.
ORIENTATION:	The epoch is 2000 January 1, noon or Julian ephemeris date 2451545.0.
	The $X_{J2000} - Y_{J2000}$ plane is the mean Earth's equator of epoch.
	The X_{J2000} axis is directed toward the mean vernal equinox of epoch.
	The Z_{J2000} axis is directed along the Earth's mean rotational axis of epoch and is positive north.
	The Y_{J2000} axis completes a right–handed system.
CHARACTERISTICS:	Inertial right–handed Cartesian system.

*A source document which discusses the expression of vectors in mean of 2000, rather than mean of 1950, coordinates is U.S. Naval Observatory Circular No. 163, "The International Astronomical Union Resolutions on Astronomical Constants, Time Scales, and the Fundamental Reference Frame," Washington, D.C. 20390, December 10, 1981.

FIGURE 3.0–1 J200, MEAN OF 2000, CARTESIAN



NAME: Mean of 2000, Polar Coordinate System

ORIGIN: For position – the center of the Earth.

For velocity – the point of interest, $P\ (X_{J2000}, Y_{J2000}, Z_{J2000})$.

ORIENTATION AND DEFINITIONS:

For position – same as in J2000 mean of 2000, Cartesian.

For velocity –

Reference plane is perpendicular to radius vector R_{J2000} from center of Earth to point *P* of interest

Reference direction is northerly along the meridian containing *P*

Polar position coordinates of *P* are:

α_{J2000}, right ascension, is the angle between projection of radius vector in the equatorial plane and the vernal equinox of epoch, positive toward east

δ_{J2000}, declination, is the angle between the radius vector and the mean Earth’s equator of epoch, positive toward north

R_{J2000}, magnitude of R_{M2000}.

Polar velocity coordinates of *P* are:

Let *U, E, N* denote up, east, and north directions; then:

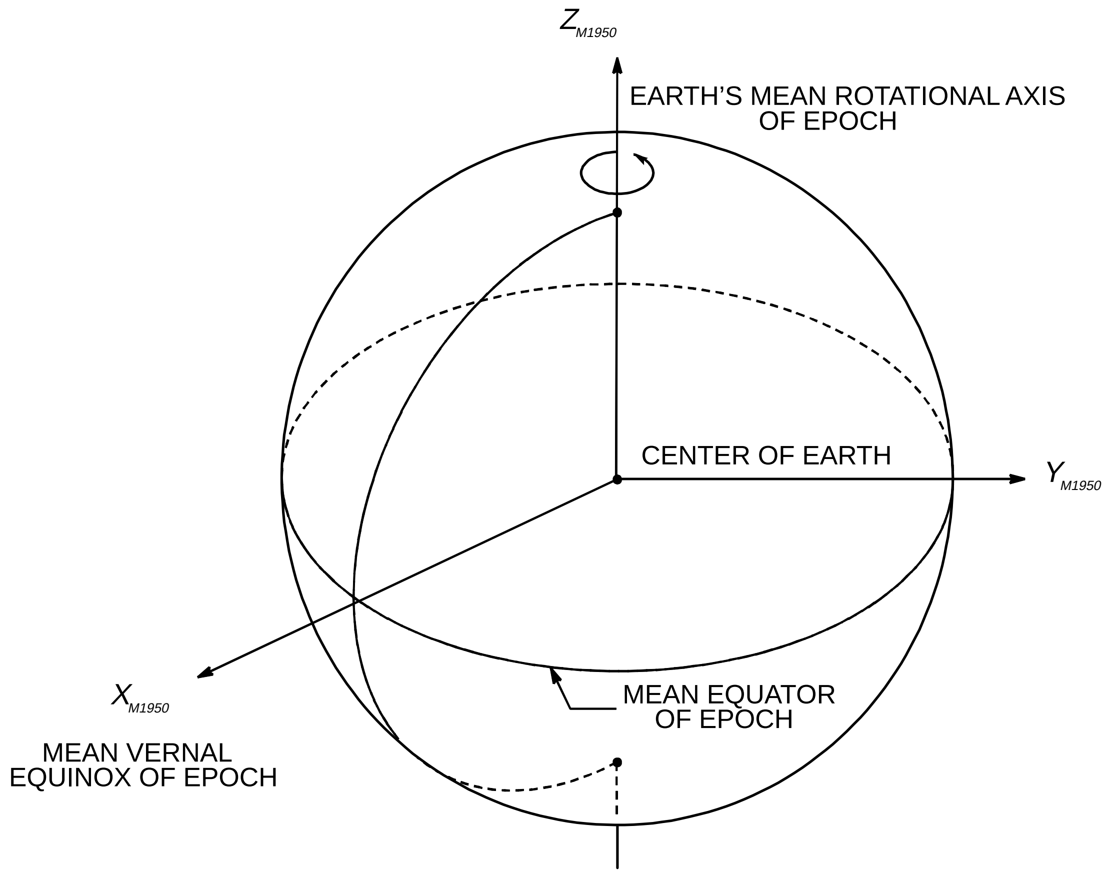
ψ_{J2000}, azimuth, is the angle from north to the projection of the inertial velocity, V_{2000}, on the reference plane, positive toward east

γ_{J2000}, flightpath angle, is the angle between the reference plane and V_{M2000}, positive sense toward *U*

V_{J2000}, magnitude of V_{J2000}

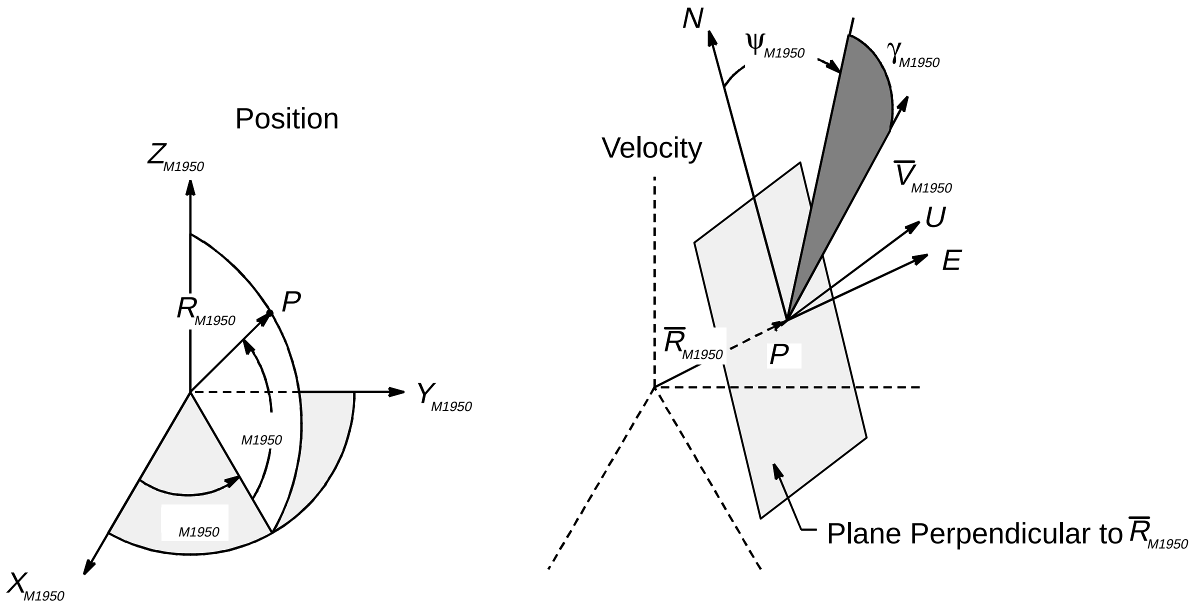
CHARACTERISTICS: Inertial.

FIGURE 3.0–2 MEAN OF 2000, POLAR



NAME:	Mean of 1950, Cartesian Coordinate System
ORIGIN:	The center of the Earth.
ORIENTATION:	The epoch is the beginning of Besselian year 1950 or Julian ephemeris date 2433282.423357.
	The $X_{M1950} – Y_{M1950}$ plane is the mean Earth's equator of epoch.
	The X_{M1950} axis is directed toward the mean vernal equinox of epoch.
	The Z_{M1950} axis is directed along the Earth's mean rotational axis of epoch and is positive north.
	The Y_{M1950} axis completes a right–handed system.
CHARACTERISTICS:	Inertial right–handed Cartesian system.
NOTES:	This coordinate system is provided to support existing analyses framework. Any new analyses tasks should utilize the J2000, Cartesian Coordinate System depicted in Figure 3.0–1. This coordinate system is also referred to as B1950.

FIGURE 3.0–3 MEAN OF 1950, CARTESIAN



NAME: Mean of 1950, Polar Coordinate System

ORIGIN: For position – the center of the Earth.

For velocity – the point of interest, $P(X_{M1950}, Y_{M1950}, Z_{M1950})$.

ORIENTATION AND DEFINITIONS:

For position – same as in mean of 1950, Cartesian.

For velocity –

Reference plane is perpendicular to radius vector R_{M1950} from center of Earth to point *P* of interest

Reference direction is northerly along the meridian containing *P*

Polar position coordinates of *P* are:

α_{M1950}, right ascension, is the angle between projection of radius vector in the equatorial plane and the vernal equinox of epoch, positive toward east

δ_{M1950}, declination, is the angle between the radius vector and the mean Earth's equator of epoch, positive toward north

R_{M1950}, magnitude of R_{M1950}

Polar velocity coordinates of *P* are:

Let *U, E, N* denote up, east, and north directions; then:

ψ_{M1950}, azimuth, is the angle from north to the projection of V_{M1950} on the reference plane, positive toward east

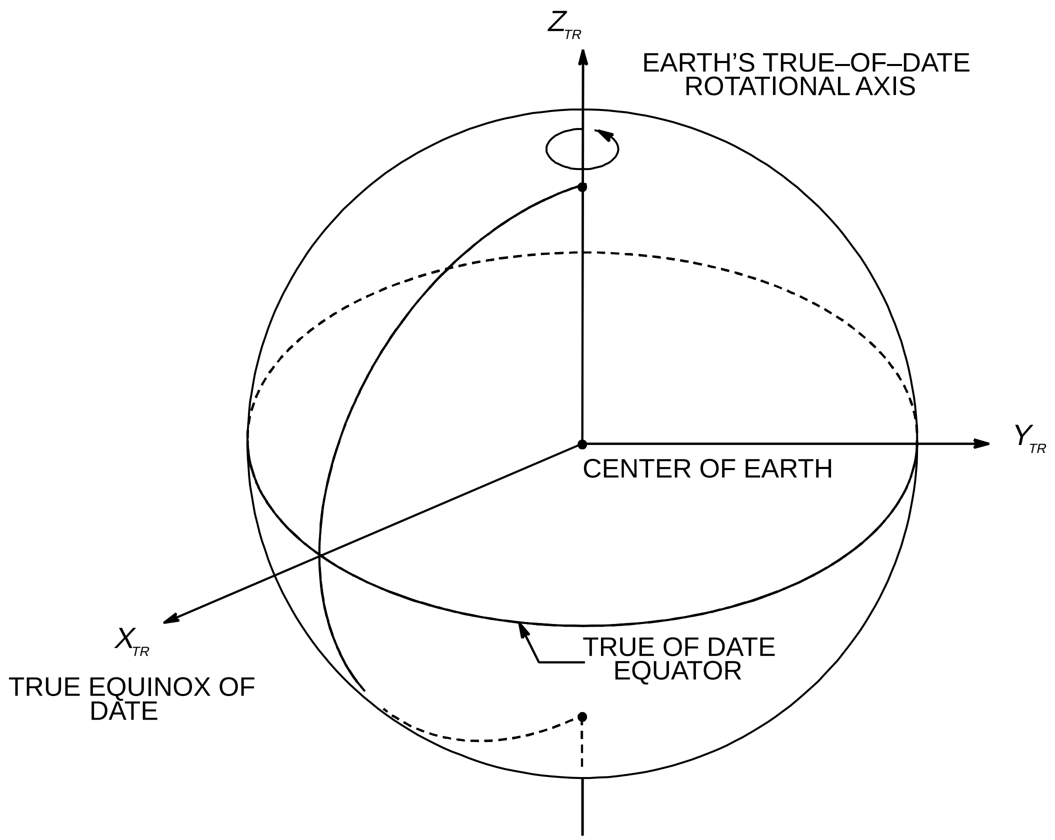
γ_{M1950}, flightpath angle, is the angle between the reference plane and V_{M1950}; positive sense toward *U*

V_{M1950}, magnitude of V_{M1950}

CHARACTERISTICS: Inertial.

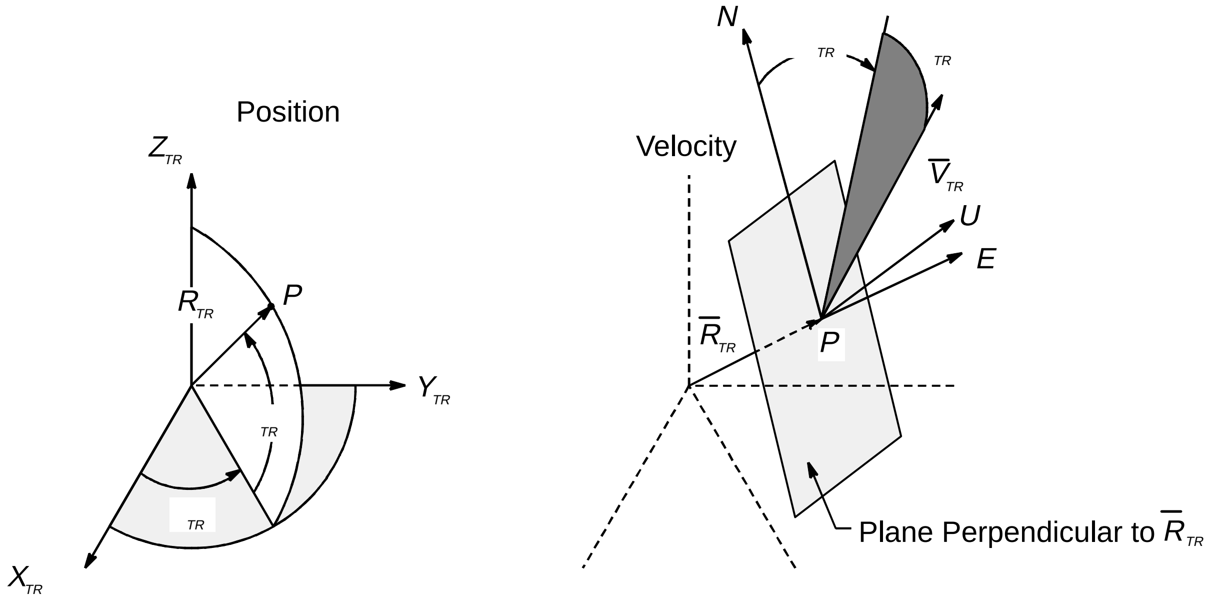
NOTE: This coordinate system is provided to support existing analyses framework. Any new analyses tasks should utilize the J2000, Polar Coordinate System depicted in Figure 3.0–2.

FIGURE 3.0–4 MEAN OF 1950, POLAR



NAME:	True of Date, Cartesian Coordinate System
ORIGIN:	The center of the Earth.
ORIENTATION:	The epoch is the current time of interest.
	The $X_{TR} - Y_{TR}$ plane is the Earth's true equator of epoch.
	The X_{TR} axis is directed toward the true vernal equinox of epoch.
	The Z_{TR} axis is directed along the Earth's true rotational axis of epoch and is positive north.
	The Y_{TR} axis completes a right–handed system.
CHARACTERISTICS:	Quasi–inertial right–handed Cartesian.

FIGURE 3.0–5 TRUE OF DATE, CARTESIAN



NAME:	True of Date, Polar Coordinate System
ORIGIN:	For position – the center of the Earth.
	For velocity – the point of interest, $P\ (X_{TR}, Y_{TR}, Z_{TR})$.
ORIENTATION:	For position – same as in True Of Date (TOD), Cartesian.
	For velocity –

Reference plane is perpendicular to radius vector R_{TR} from center of Earth to point *P* of interest

Reference direction is northerly along the meridian containing *P*

Polar position coordinates of *P* are:

α_{TR}, right ascension, is the angle between projection of radius vector in the equatorial plane and the true vernal equinox of epoch, measured positive toward the east

δ_{TR}, declination, is the angle between the radius vector and the Earth's true equatorial plane of epoch, positive toward the north

R_{TR} is the magnitude of R_{TR}

Polar velocity coordinates of *P* are:

Let *U, E, N* denote up, east, and north directions; then:

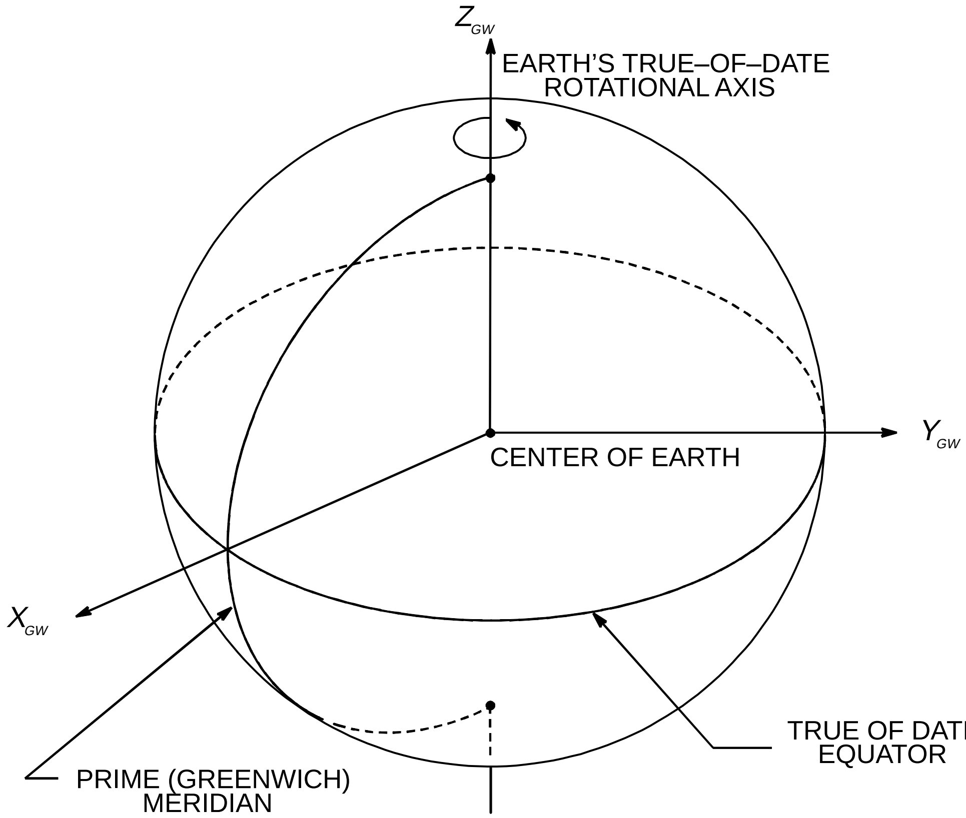
ψ_{TR}, azimuth, is the angle from north to the projection of the inertial velocity, V_{TR}, on the reference plane, positive toward east

γ_{TR}, flightpath angle, is the angle between the reference plane and V_{TR}; positive toward *U*

V_{TR}, magnitude of V_{TR}

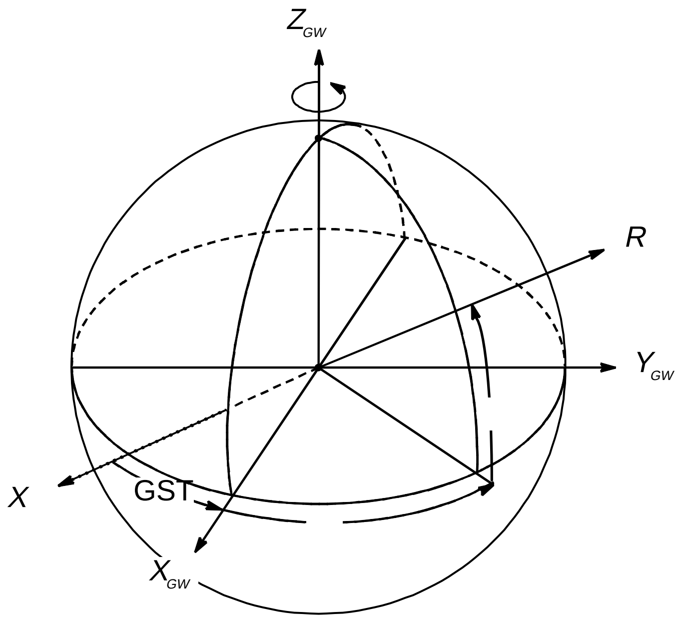
CHARACTERISTICS: Quasi–inertial.

FIGURE 3.0–6 TRUE OF DATE, POLAR



NAME:	Greenwich True of Date Coordinate System
ORIGIN:	The center of the Earth.
ORIENTATION:	The $X_{GW} - Y_{GW}$ plane is the Earth's TOD equator.
	The Z_{GW} axis is directed along the Earth's TOD rotational axis and is positive north.
	The $+ X_{GW}$ axis is directed toward the prime meridian.
	The Y_{GW} axis completes a right–handed system.
CHARACTERISTICS:	Rotating right–handed Cartesian. Velocity vectors expressed in this system are relative to a rotating reference frame fixed to the Earth.

FIGURE 3.0–7 GREENWICH TRUE OF DATE, CARTESIAN



NAME: Greenwich True of Date, Polar Coordinate System

ORIGIN: For position – the center of the Earth.

For velocity – the point of interest.

ORIENTATION: For position – Same as the Greenwich true–of–date, Cartesian.

For velocity – Same as the TOD, Polar .

Polar position coordinates are:

R, radius, distance from center of the Earth

$R = \sqrt{X_{GW}{}^2 + Y_{GW}{}^2 + Z_{GW}{}^2}$

λ, longitude, angular distance (positive east, negative west, limits ±180 degrees) between the prime meridian (Greenwich) and the current or instantaneous meridian:

$\lambda = \tan^{-1}\left(\frac{Y_{GW}}{X_{GW}}\right)$

δ, “latitude” or strictly geocentric declination, angular distance (positive north, negative south, limits ± 90 degrees) between the radius vector and its projection onto the equatorial plane.

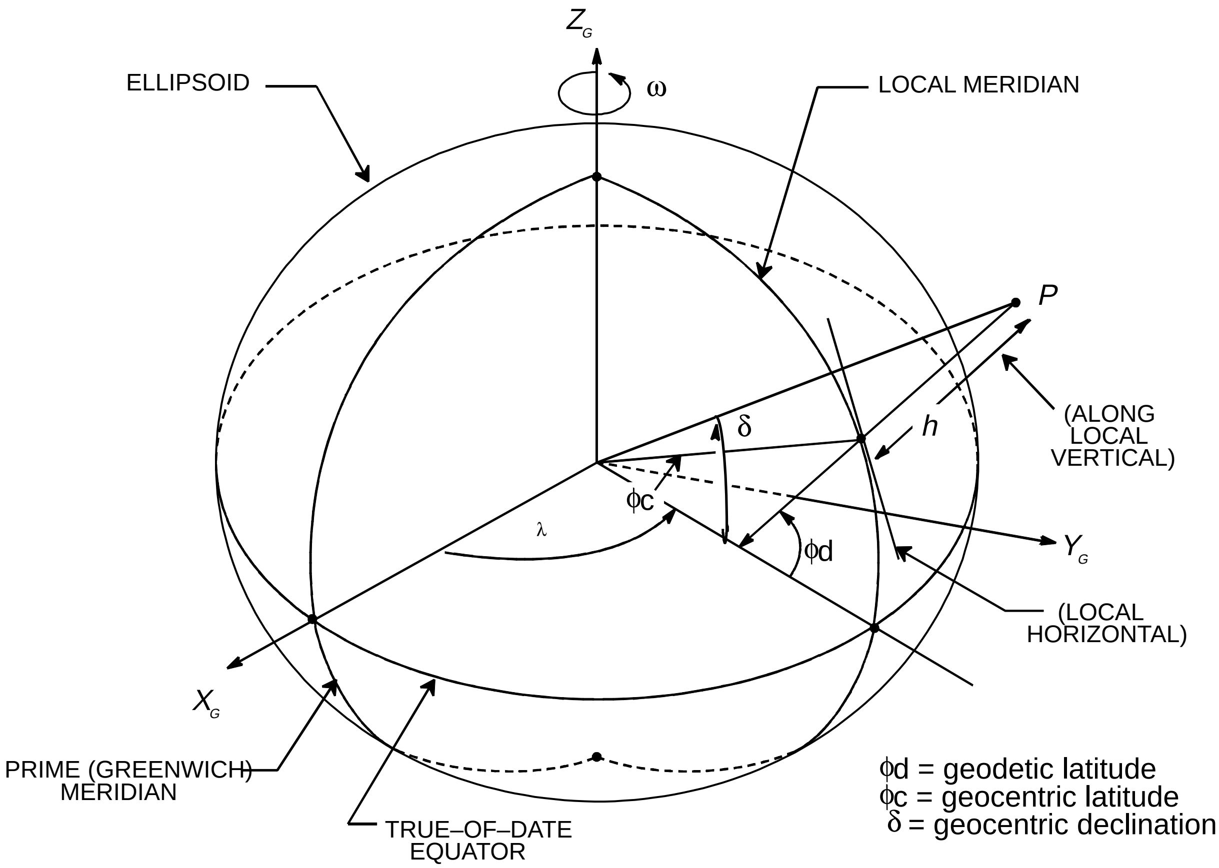
$\delta = \sin^{-1}\left(\frac{Z_{GW}}{R}\right)$

Polar velocity coordinates are the same as the TOD polar velocity coordinates (fig. 3.0–6)

CHARACTERISTICS: Quasi–inertial.

NOTE: The Greenwich True Of Date (GTOD) Coordinate System is related to the TOD Coordinate System by the Greenwich Sidereal Time (GST), the angle between the TOD vernal equinox and the Greenwich meridian. The GST is zero at the instant when the Greenwich meridian passes through the vernal equinox, and it increases at the rate ω = 15.041068...deg/hr. The longitude, λ, measured in the GTOD system and the right ascension, α, measured in the TOD system are related by λ = α – GST.

FIGURE 3.0–8 GREENWICH TRUE OF DATE, POLAR



NAME: Geodetic Coordinate System

This system consists of a set of parameters rather than a coordinate system; therefore, no origin is specified.

ORIENTATION: This system of parameters is based on an ellipsoidal model of the Earth. For any point of interest, a line, known as the Geodetic Local Vertical, is defined as perpendicular to the ellipsoid from the point of interest.

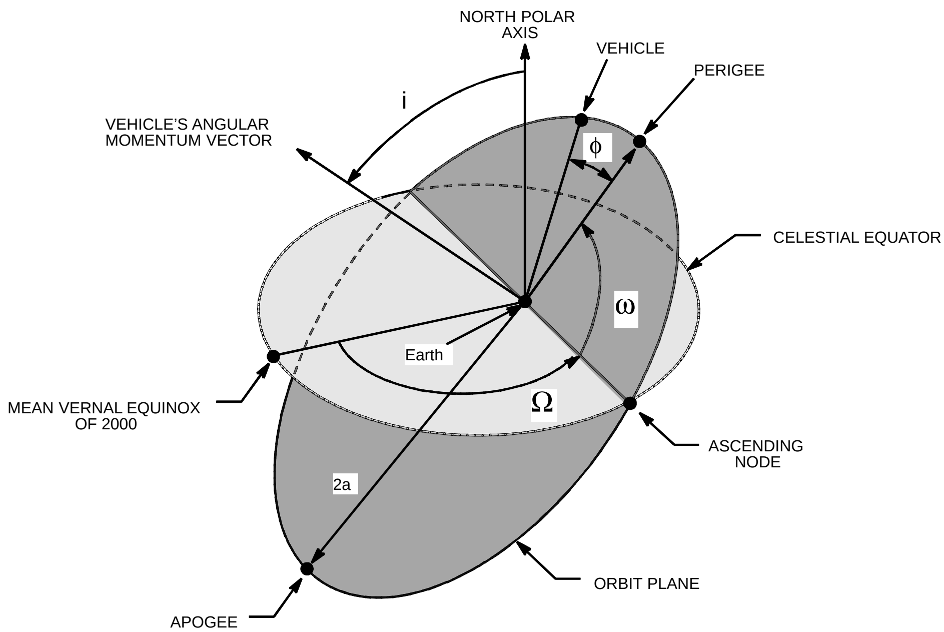
h, geodetic altitude, is the distance from the point of interest to the reference ellipsoid, measured along the geodetic local vertical, and is positive for points outside the ellipsoid.

λ is the longitude measured in the plane of the Earth's true equator from the prime (Greenwich) meridian to the local meridian, measured positive eastward.

ϕ_d is the geodetic latitude, measured in the plane of the local meridian from the Earth's true equator to the geodetic local vertical, measured positive north from the equator.

CHARACTERISTICS: Rotating polar coordinate parameters. Usually only position vectors are expressed in this coordinate system. The reference ellipsoid model should be used with this system.

FIGURE 3.0–9 GEODETIC



NAME: Orbital Element System

ORIGIN: The center of the Earth.

ORIENTATION AND DEFINITIONS:

The reference for computing osculating orbital elements is the J2000 Coordinate System.

a is the instantaneous semimajor axis of the orbit.

e is the instantaneous eccentricity of the orbit.

i, the inclination of the orbital plane, is the instantaneous angle between the mean inertial north polar axis and the orbital angular momentum vector.

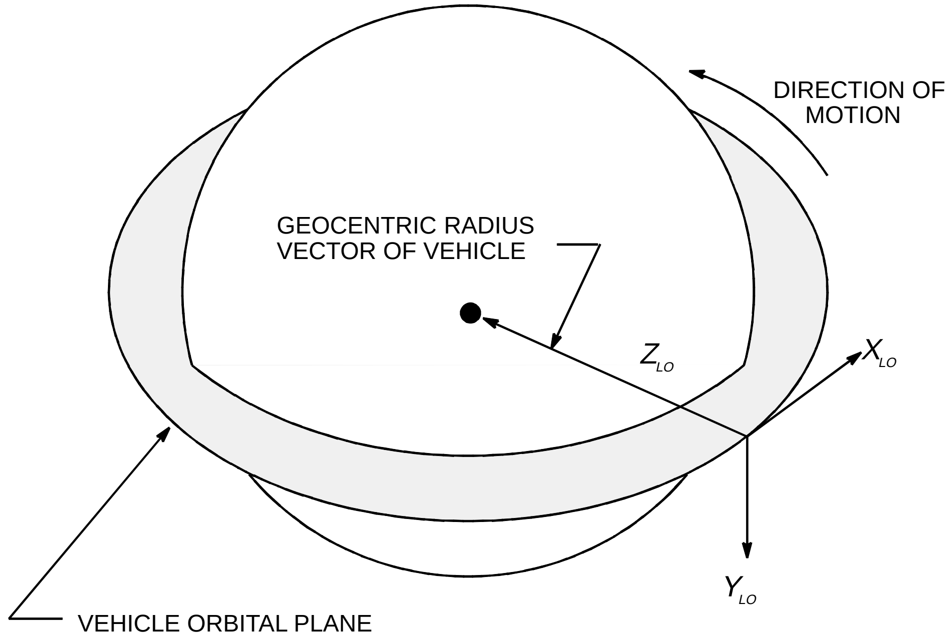
Ω, the right ascension of the ascending node, is the angle measured eastward from the vernal equinox along the equator to that intersection with the orbit plane where the vehicle passes from south to north. In the case where inclination equals zero, the ascending node is defined to be the X–axis of the inertial reference system.

ω, the argument of perigee, is the angle measured in the orbit plane between the ascending node and perigee, positive in the direction of travel in the orbit. In the case where eccentricity equals zero, perigee is defined to be at the ascending node.

ϕ, the true anomaly, is the geocentric angular displacement of the vehicle measured from perigee in the orbit plane, and positive in the direction of travel in the orbit.

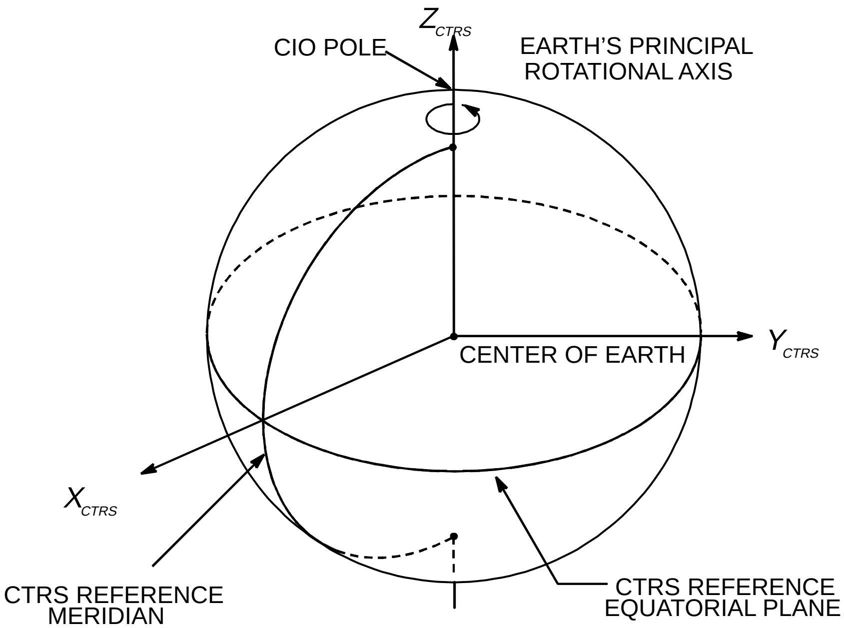
CHARACTERISTICS: Quasi–inertial.

FIGURE 3.0–10 ORBITAL ELEMENTS



NAME:	Local Orbital (LVLH) Coordinate System
ORIGIN:	Vehicle center of mass.
ORIENTATION:	The $X_{LO} - Z_{LO}$ plane is the instantaneous orbit plane at the time of interest.
	The Z_{LO} axis lies along the geocentric radius vector to the vehicle and is positive toward the center of the Earth.
	The Y_{LO} axis is normal to the orbit plane, opposite of the orbit momentum vector.
	The X_{LO} axis completes the right–handed orthogonal system and positive in the direction of the vehicle motion.
CHARACTERISTICS:	Rotating right–handed Cartesian Coordinate System.

FIGURE 3.0–11 LOCAL ORBITAL: LOCAL VERTICAL LOCAL HORIZONTAL



NAME: Conventional Terrestrial Reference System Coordinate System

TYPE: Rotating Right–Handed Cartesian

DESCRIPTION: The Conventional Terrestrial Reference System (CTRS) is an updated Earth–fixed system that incorporates polar motion. The CTRS assumes a spherical Earth and does not take any flattening factors into account, therefore, any definitions of altitude should be derived from the Geodetic Coordinate System (Figure 3.0–9). The CTRS is related to the GTOD (Figure 3.0–8) by the transformation:

$$\begin{pmatrix} x \\ y \\ z \end{pmatrix}_{CTRS} = \begin{bmatrix} 1 & 0 & xp \\ 0 & 1 & yp \\ -xp & yp & 1 \end{bmatrix} \begin{pmatrix} x \\ y \\ z \end{pmatrix}_{GTOD}$$

where xp and yp are the angular coordinates (very small angles measured in tenths of an arc–second) of the Celestial Ephemeris Pole (CEP) with respect to the Conventional International Origin (CIO)expressed in CTRS. This data is published weekly by the U.S. Naval Observatory in the International Earth Rotation Service Bulletin–A. The Global Positioning Satellite (GPS) ephemerides are maintained in the CTRS.

ORIGIN: The origin is located at the Earth's Center.

ORIENTATION: The pole of this system is known as the CIO.

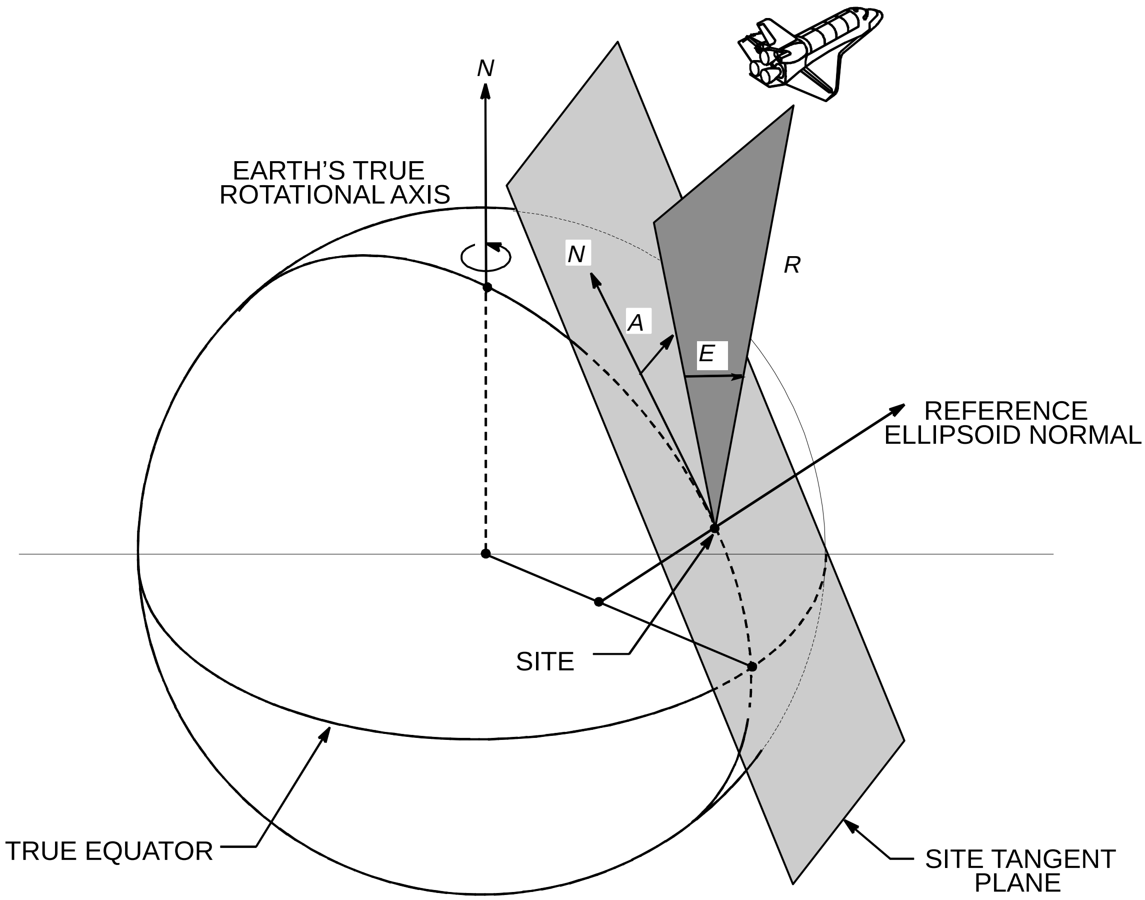
Z_{CTRS} The Z–axis is coincident with the Earth's principal rotational axis. The positive Z–axis is directed toward the CIO.

X_{CTRS} The positive X–axis passes through the intersection of the CTRS reference equatorial plane and the CTRS reference meridian.

Y_{CTRS} The positive Y–axis completes the rotating right–handed Cartesian system.

SUBSCRIPT: CTRS

FIGURE 3.0–12 CONVENTIONAL TERRESTRIAL REFERENCE SYSTEM



NAME: Ground Site Azimuth–Elevation Mount Coordinate System

ORIGIN: The intersection of the site axes.

ORIENTATION AND DEFINITIONS:

The site tangent plane contains the site and is perpendicular to the reference ellipsoid normal which passes through the site.

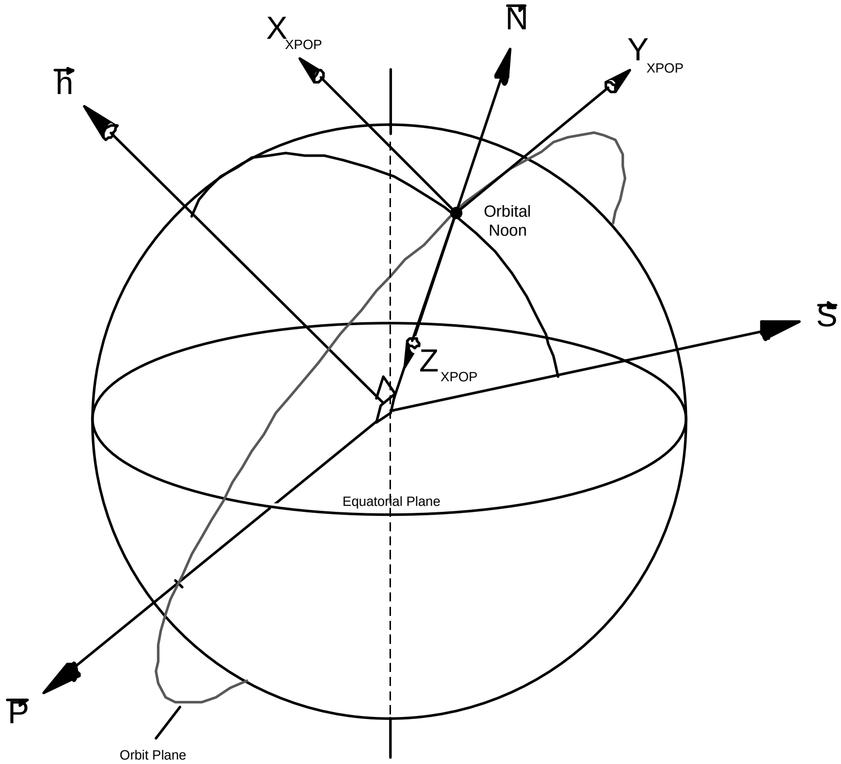
R is the slant range to the vehicle.

A is the azimuth angle measured clockwise from true north to the projection of the slant–range vector into the site tangent plane.

E is the elevation angle measured positive above the site tangent plane to the slant–range vector.

CHARACTERISTICS: Rotating, Earth–referenced.

FIGURE 3.0–13 GROUND SITE AZIMUTH–ELEVATION MOUNT



NAME: XPOP Quasi–Inertial Coordinate System

ORIGIN: Vehicle Center of Mass

ORIENTATION AND DEFINITIONS:

The X_{XPOP} – Z_{XPOP} plane is aligned with the orbit angular momentum vector and sun vector.

The X_{XPOP} axis is aligned with the orbit angular momentum vector.

The Z_{XPOP} axis is aligned with the orbital noon vector, positive in the negative orbital noon direction.

The Y_{XPOP} axis lies in the vehicle orbit plane and completes the right–handed coordinate system.

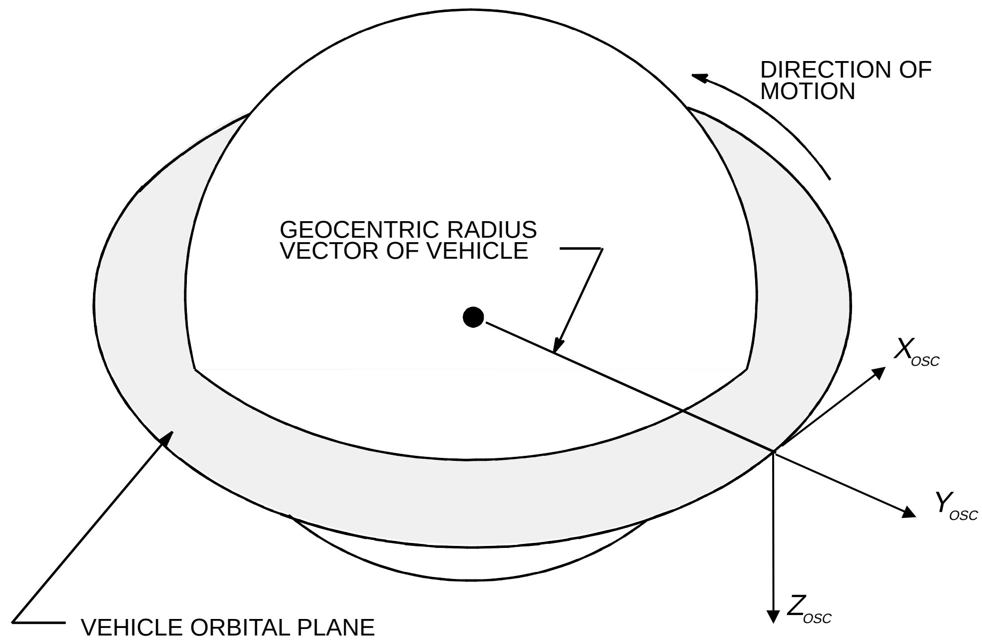
$\vec{N}$ = Unit Orbital Noon Vector
$\vec{h}$ = Unit Angular Momentum Vector
$\vec{S}$ = Unit Sun Vector (at orbit noon)
$\vec{P}$ = Unit Perpendicular Vector To S & h Plane, (S X h)

$$X_{XPOP} = \vec{h}$$
$$Y_{XPOP} = \vec{h} \times \vec{S}$$
$$Z_{XPOP} = (\vec{S} \times \vec{h}) \times \vec{h}$$

$$\vec{N} = \vec{h} \times (\vec{S} \times \vec{h})$$

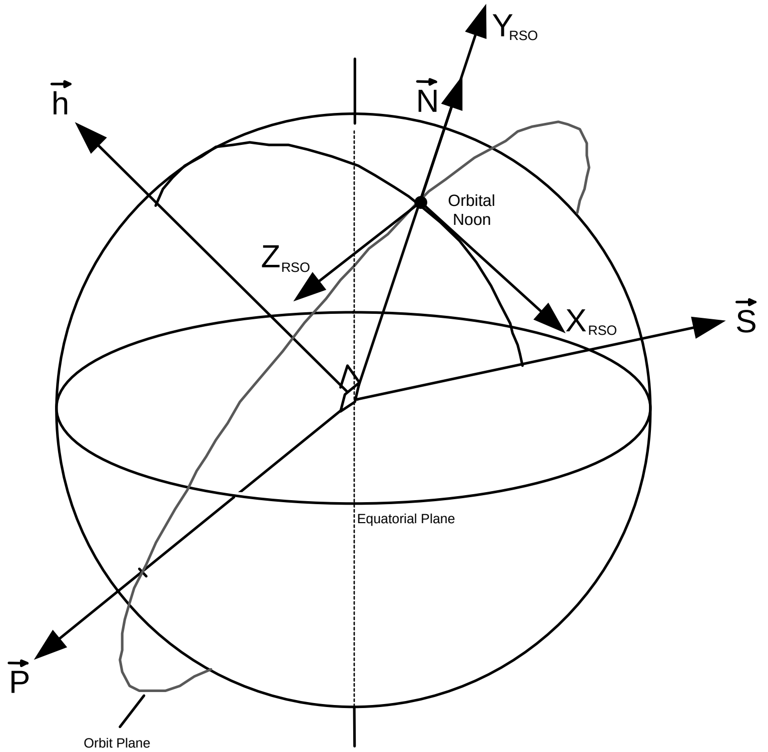
CHARACTERISTICS: Quasi–inertial right–handed Cartesian Coordinate System.

FIGURE 3.0–14 XPOP QUASI–INERTIAL REFERENCE FRAME



NAME:	Russia Orbital System of Coordinates
DESCRIPTION:	This coordinate frame is the Russian equivalent to LVLH. The Russian name is Орбитальная Система Координат, or [ОСК].
ORIGIN:	Vehicle center of mass.
ORIENTATION:	The X_{OSC} – Y_{OSC} plane is the instantaneous orbit plane at the time of interest. The Y_{OSC} axis lies along the geocentric radius vector to the vehicle and is positive away from the center of the Earth. The Z_{OSC} axis is normal to the orbit plane, positive in the direction of the negative angular momentum vector. The X_{OSC} axis completes the set. It lies in the vehicle orbital plane, perpendicular to the Y_{OSC} and Z_{OSC} axes, and positive in the direction of vehicle motion.
CHARACTERISTICS:	Rotating right–handed Cartesian Coordinate System.
SUBSCRIPT:	OSC or [ОСК]

FIGURE 3.0–15 RUSSIA ORBITAL COORDINATES SYSTEM



NAME: Russian Sun Equilibrium Attitude Coordinate System

DESCRIPTION: This coordinate frame is the Russian equivalent to XPOP. The Russian name is Равновесная Солнечная Ориентация or [РСО].

ORIGIN: Vehicle Center of Mass

ORIENTATION AND DEFINITIONS:

The X_{RSO} – Y_{RSO} plane is aligned with the orbit angular momentum vector and sun vector.

The X_{RSO} axis is aligned with the orbit angular momentum vector, positive along the negative angular momentum vector.

The Y_{RSO} axis is aligned with the orbital noon vector, i.e., the projection of the sun vector onto the orbital plane.

The Z_{RSO} axis lies in the vehicle orbit plane and completes the right–handed coordinate system.

$\vec{N}$ = Unit Orbital Noon
$\vec{h}$ = Unit Angular Momentum Vector
$\vec{S}$ = Unit Sun Vector (at orbital noon)
$\vec{P}$ = Unit Perpendicular Vector to S & h Plane, (S X h)

$$X_{RSO} = -\vec{h}$$
$$Y_{RSO} = \vec{h} \times (\vec{S} \times \vec{h})$$
$$Z_{RSO} = \vec{S} \times \vec{h}$$

$$\vec{N} = \vec{h} \times (\vec{S} \times \vec{h})$$

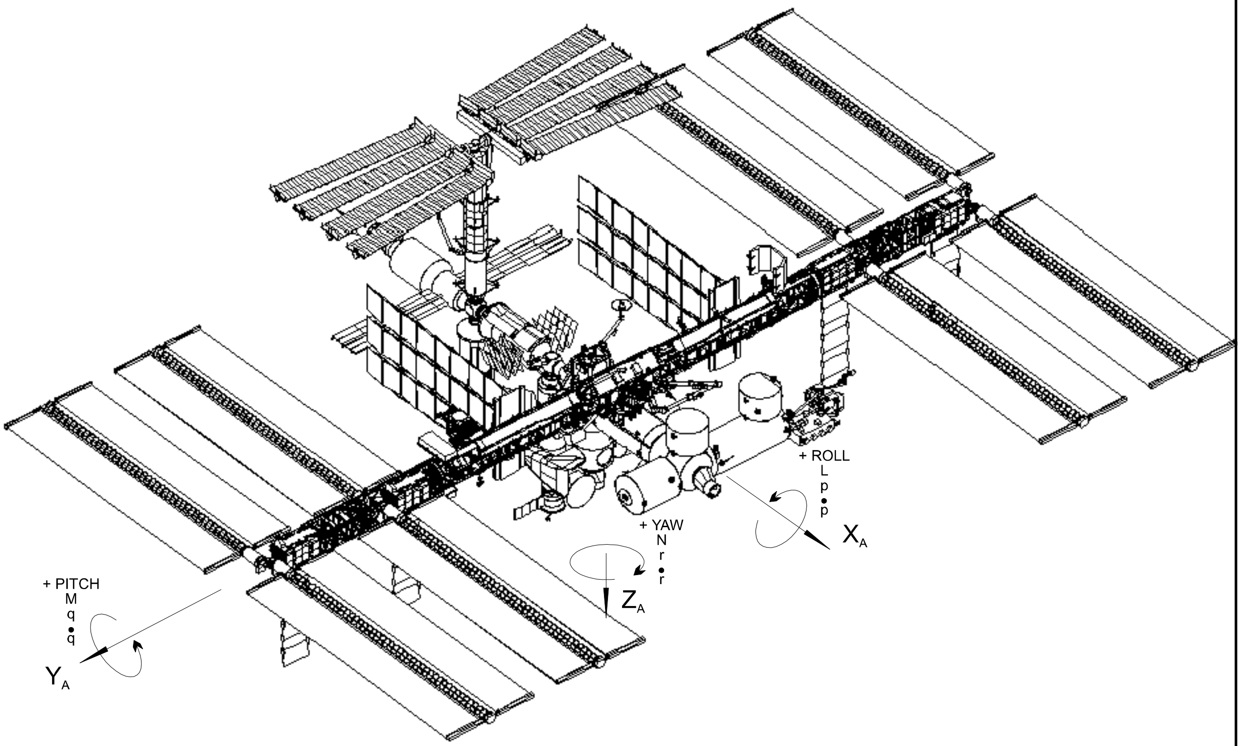
CHARACTERISTICS: Quasi–inertial right–handed Cartesian Coordinate System.

SUBSCRIPT: RSO or [PCO]

FIGURE 3.0–16 RSO: RUSSIAN SUN EQUILIBRIUM ATTITUDE COORDINATES SYSTEM

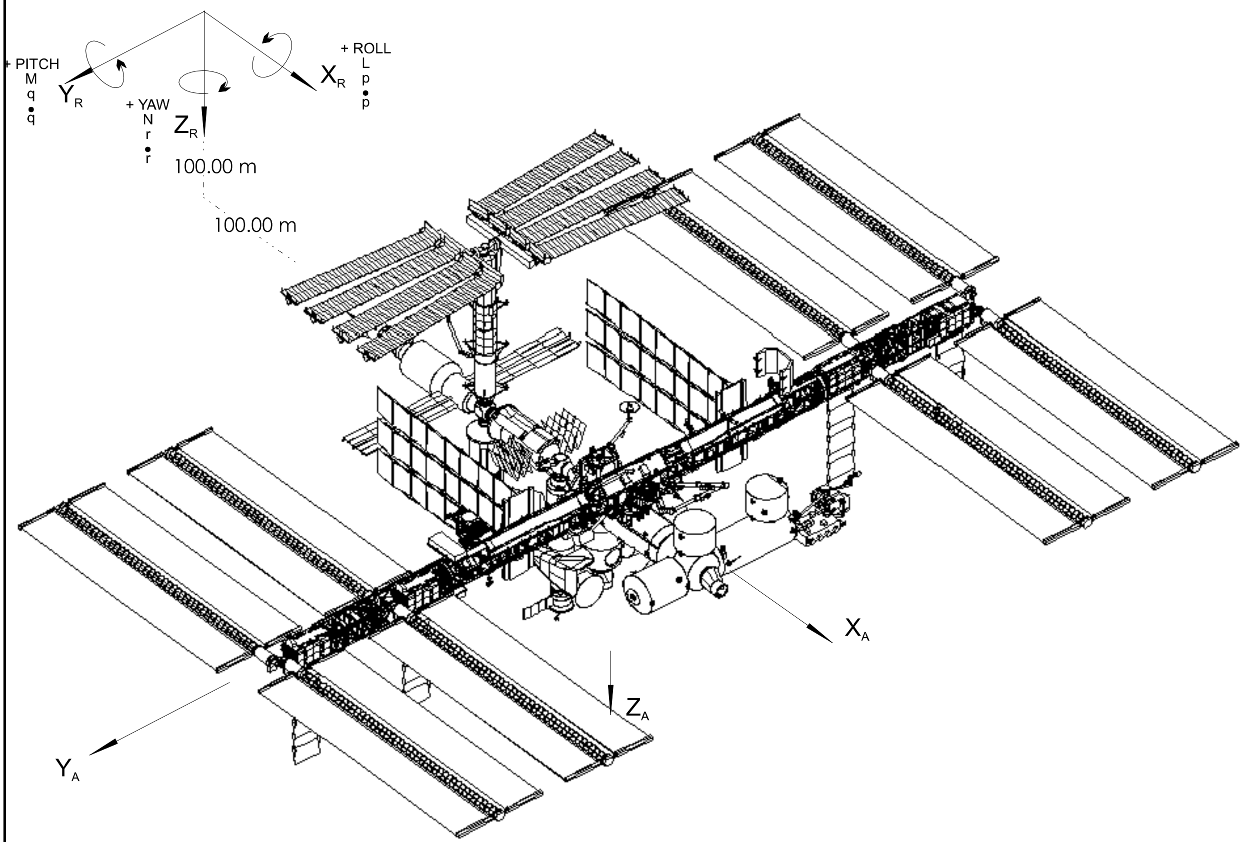
4.0 CONFIGURATION DEPENDENT REFERENCE FRAMES

The coordinate systems outlined in this chapter are dependent on the Space Station configuration as well as the Orbiter and visiting vehicle configurations. These coordinate systems differ in origin location, and orientation and the user is free to use whichever system suits the analysis being performed. All dimensions are in inches unless otherwise specified.



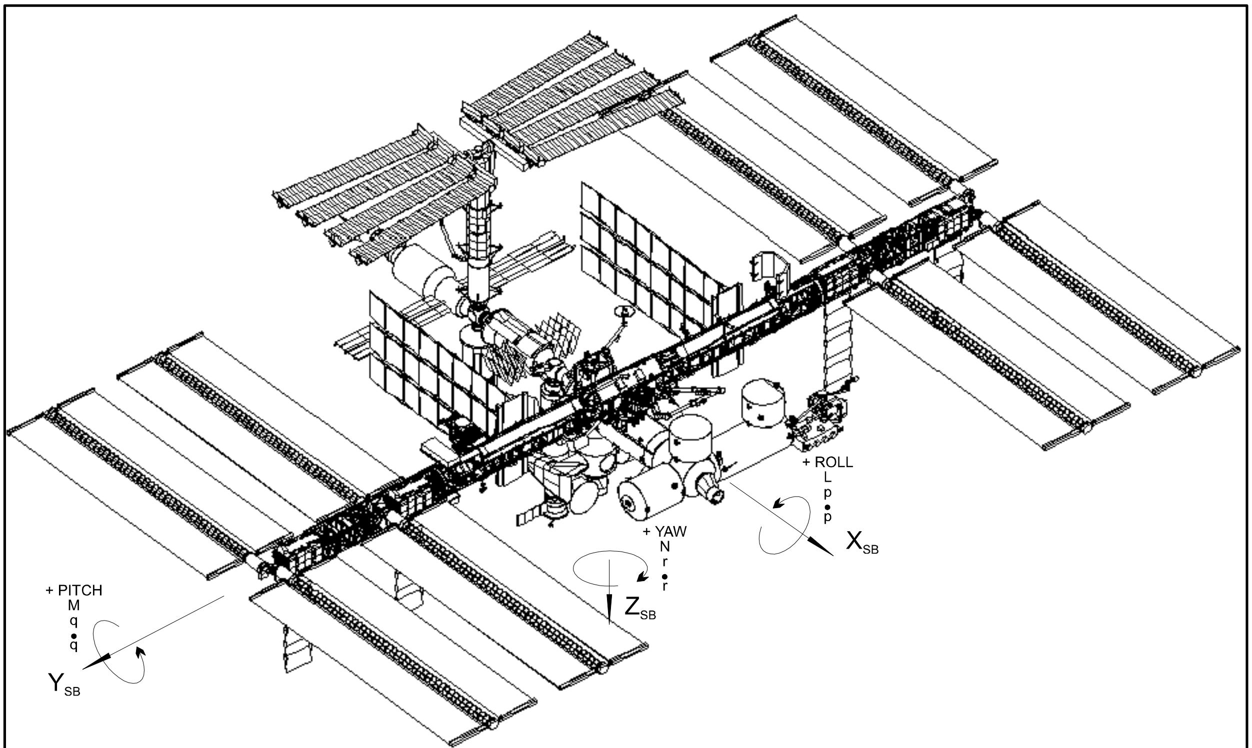
NAME:	Space Station Analysis Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
DESCRIPTION:	This coordinate system is derived using the Local Vertical Local Horizontal (LVLH) flight orientation. When defining the relationship between this coordinate system and another, the Euler angle sequence to be used is a yaw, pitch, roll sequence around the Z_A, $Y_{A,}$ and X_A axes, respectively.
ORIGIN:	The origin is located at the geometric center of Integrated Truss Segment (ITS) S0 and is coincident with the S0 Coordinate frame. See figure 5.0–12, S0 coordinate frame for a more detailed description of the S0 geometric center.
ORIENTATION:	X_A The X–axis is parallel to the longitudinal axis of the module cluster. The positive X–axis is in the forward direction. Y_A The Y axis is identical with the S_O axis. The nominal alpha joint rotational axis is parallel with Y_A. The positive Y–axis is in the starboard direction. Z_A The positive Z–axis is in the direction of nadir and completes the right–handed Cartesian system. L, M, N: Moments about X_A, $Y_{A,}$ and Z_A axes, respectively. p, q, r: Body rates about X_A, $Y_{A,}$ and Z_A axes, respectively. $\dot{p}$, $\dot{q}$, $\dot{r}$: Angular body acceleration about X_A, $Y_{A,}$ and Z_A axes, respectively.
SUBSCRIPT:	A

FIGURE 4.0–1 SPACE STATION ANALYSIS COORDINATE SYSTEM



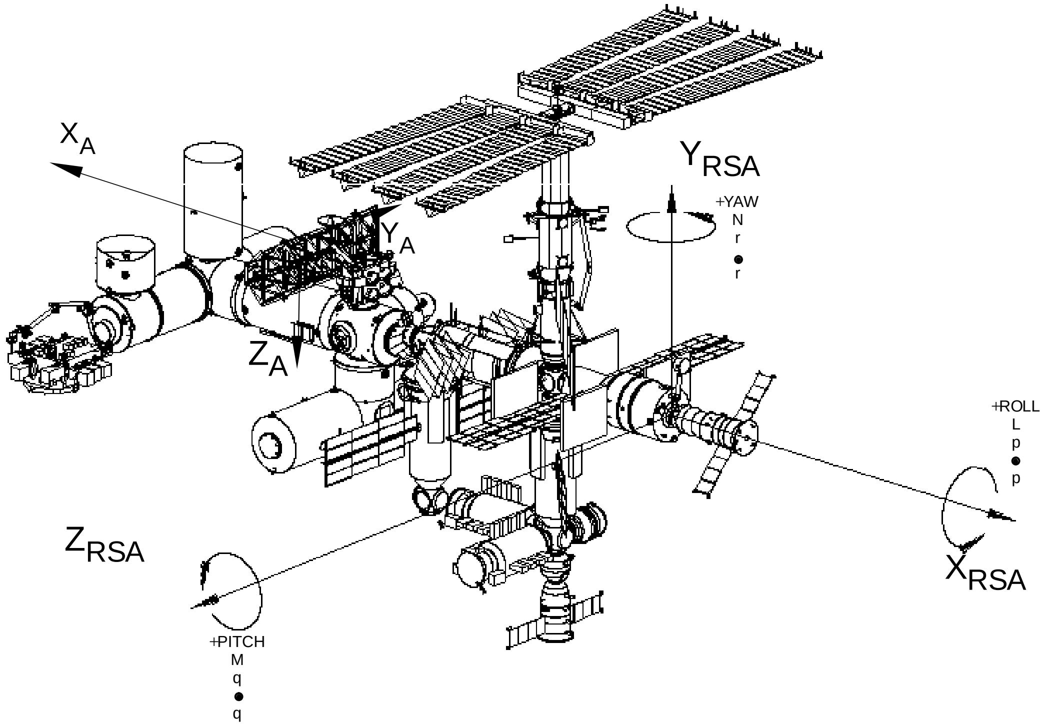
NAME:	Space Station Reference Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
DESCRIPTION:	This coordinate system is derived using the LVLH flight orientation.
ORIGIN:	The datum point is located at the origin of the Space Station Analysis Coordinate System frame. The origin of the Space Station Reference Coordinate System is located such that the datum point is located at X_R=100, Y_R=0, and Z_R=100 meters.
ORIENTATION:	X_R The X–axis is parallel to the X_A. The positive X–axis is in the forward direction. Y_R The Y–axis is parallel with the nominal alpha joint rotational axis which is coincident to Y_A. The positive Y–axis is in the starboard direction. Z_R The positive Z–axis is parallel to Z_A and is in the direction of nadir and completes the rotating right–handed Cartesian system. L, M, N: Moments about X_R, Y_R, and Z_R axes, respectively. p, q, r: Body rates about X_R, Y_R, and Z_R axes, respectively. $\dot{p}$, $\dot{q}$, $\dot{r}$: Angular body acceleration about X_R, Y_R, and Z_R axes, respectively.
SUBSCRIPT:	R

FIGURE 4.0–2 SPACE STATION REFERENCE COORDINATE SYSTEM



NAME:	Space Station Body Coordinate System
TYPE:	Right–handed Cartesian system, Body–Fixed
DESCRIPTION:	When defining the relationship between this coordinate system and another, the Euler angle sequence to be used is a yaw, pitch, roll sequence around the Z_{SB}, Y_{SB}, and X_{SB} axes, respectively.
ORIGIN:	The origin is located at the Space Station center of mass.
ORIENTATION:	The X_{SB} axis is parallel to the X_A axis. Positive X_{SB} is in the forward flight direction.
	The Y_{SB} axis is parallel to the Y_A. Positive Y_{SB} is toward starboard.
	The Z_{SB} axis is parallel with the Z_A. Positive Z_{SB} is approximately toward nadir and completes the right–handed system X_{SB}, Y_{SB}, Z_{SB}.
	L, M, N: Moments about X_{SB}, Y_{SB}, and Z_{SB} axes, respectively.
	p, q, r: Body rates about X_{SB}, Y_{SB}, and Z_{SB} axes, respectively.
	$\dot{p}$, $\dot{q}$, $\dot{r}$: Angular body acceleration about X_{SB}, Y_{SB}, and Z_{SB} axes, respectively.
SUBSCRIPT:	SB

FIGURE 4.0–3 SPACE STATION BODY COORDINATE SYSTEM



NAME: RSA Analysis Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed

ORIGIN: The origin is located at the center of the aft side of the aft Service Module Bulkhead, aligned with the SM coordinate frame.

ORIENTATION: The X_{RSA} axis is parallel to the X_A axis. Positive X_{RSA} is opposite X_A.

The Z_{RSA} axis is parallel to the Y_A. Positive Z_{RSA} is toward port.

The Y_{RSA} axis is parallel with the Z_A. Positive Y_{RSA} is opposite of Z_A.

L, M, N: Moments about X_{RSA}, Y_{RSA}, and Z_{RSA} axes, respectively.

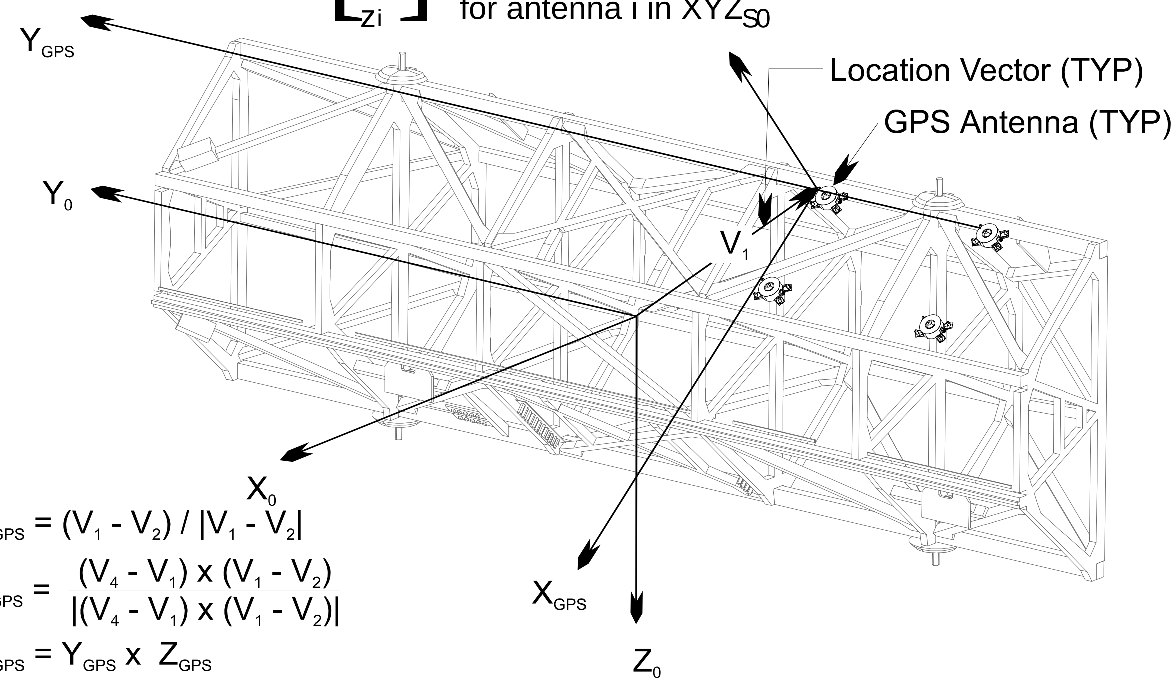
p, q, r: Body rates about X_{RSA}, Y_{RSA}, and Z_{RSA} axes, respectively.

$\dot{p}$, $\dot{q}$, $\dot{r}$: Angular body acceleration about X_{RSA}, Y_{RSA}, and Z_{RSA} axes, respectively.

SUBSCRIPT: RSA

FIGURE 4.0–4 RSA ANALYSIS COORDINATE SYSTEM

Let: $V_i = \begin{bmatrix} x_i \\ y_i \\ z_i \end{bmatrix}$ = coordinates of upper left mounting hole for antenna i in XYZ_{S0}



$$Y_{GPS} = (V_1 - V_2) / |V_1 - V_2|$$

$$Z_{GPS} = \frac{(V_4 - V_1) \times (V_1 - V_2)}{|(V_4 - V_1) \times (V_1 - V_2)|}$$

$$X_{GPS} = Y_{GPS} \times Z_{GPS}$$

NAME: GPS Antenna Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed, Hardware Specific.

DESCRIPTION: The GPS Antenna Coordinate System is the reference frame for attitude measurements output by the onboard GPS Receiver/Processor, and is the frame in which attitude knowledge requirements are expressed.

ORIGIN: The origin is located at the center of the upper left bolthole for GPS antenna #1, in the plane of the outer surface of the mounting plate.

ORIENTATION:

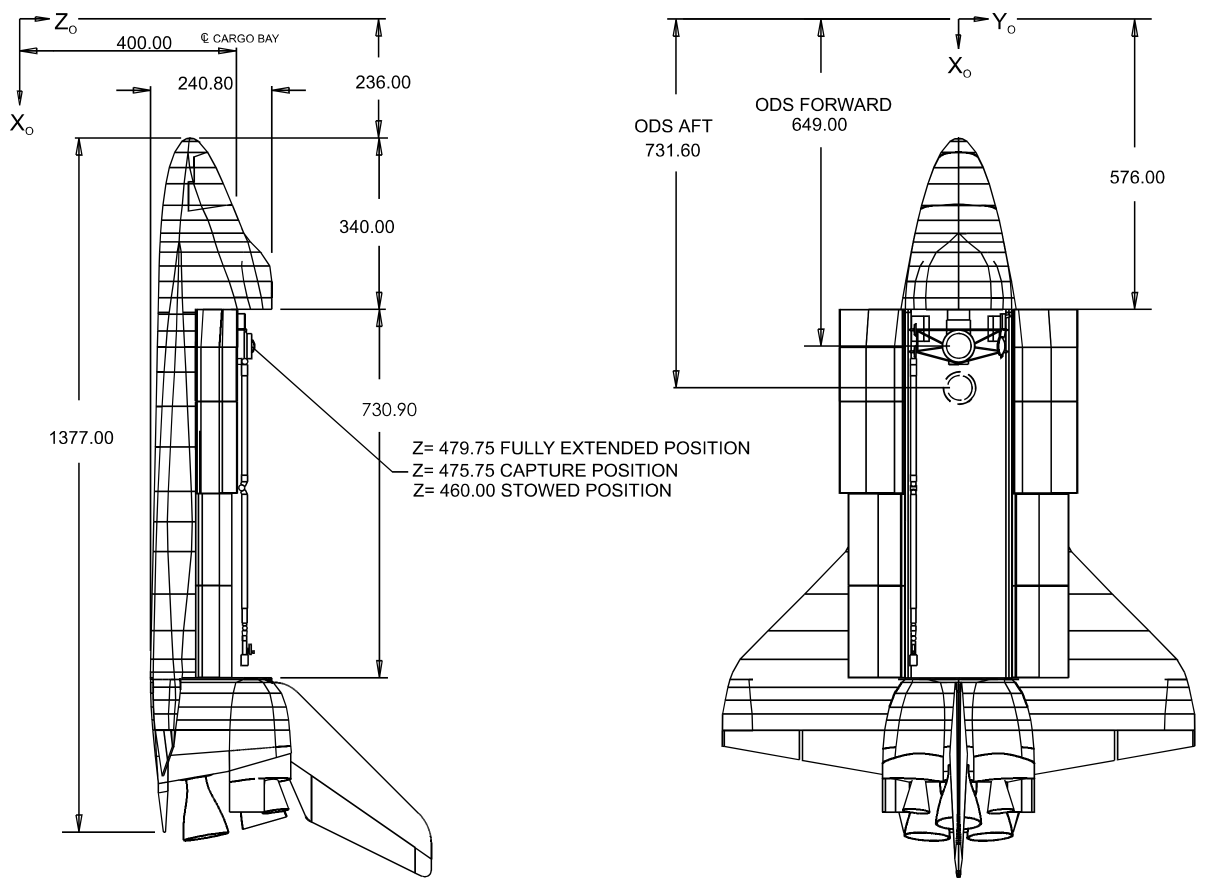
X_{GPS} Completes the set X_{GPS} , Y_{GPS} , Z_{GPS}

Y_{GPS} Along the line from the upper left bolthole for GPS antenna #2 to the upper left bolthole of GPS antenna #1

Z_{GPS} Perpendicular to the plane formed by the upper left boltholes for GPS antennas #1, #2, and #4, and positive in the general direction of the S0 Z axis

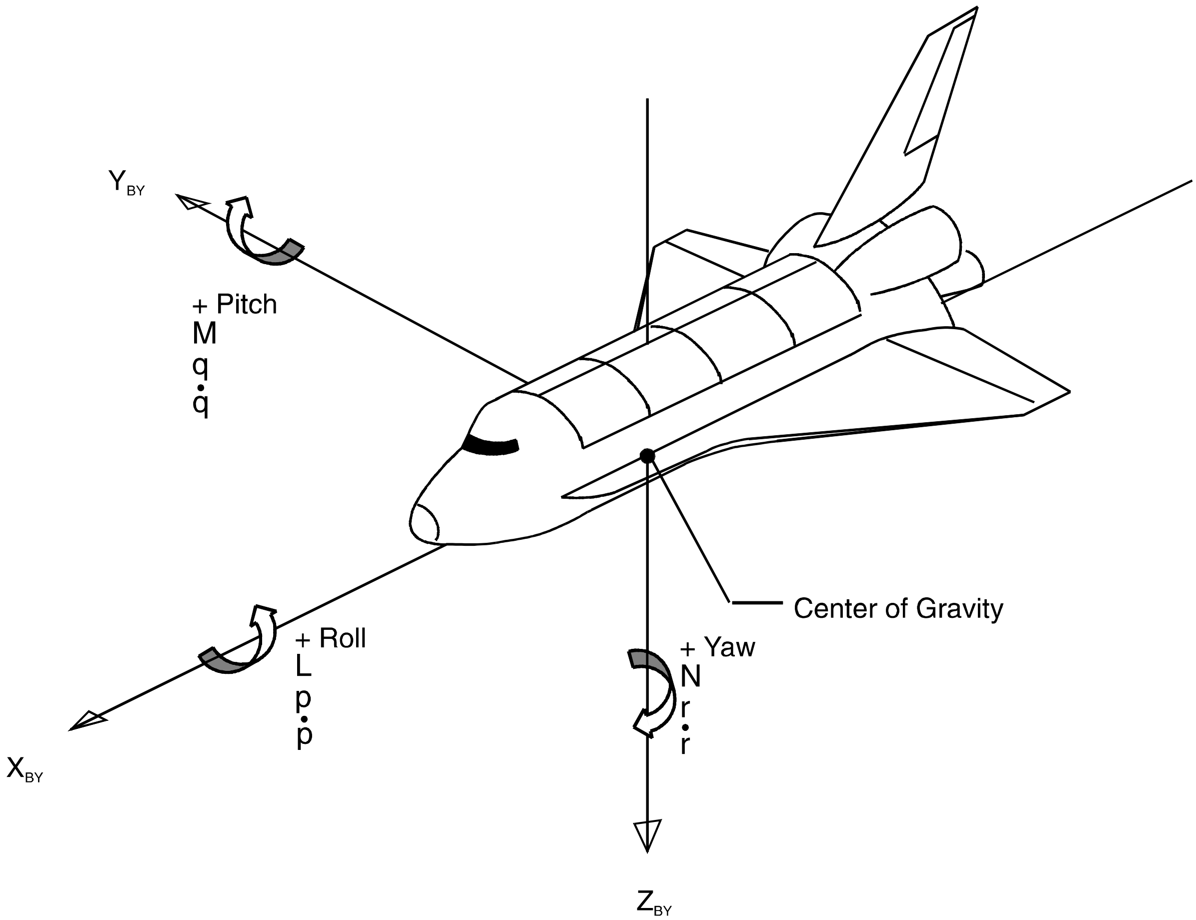
SUBSCRIPT: GPS

FIGURE 4.0–5 SPACE STATION GPS ANTENNA COORDINATE SYSTEM



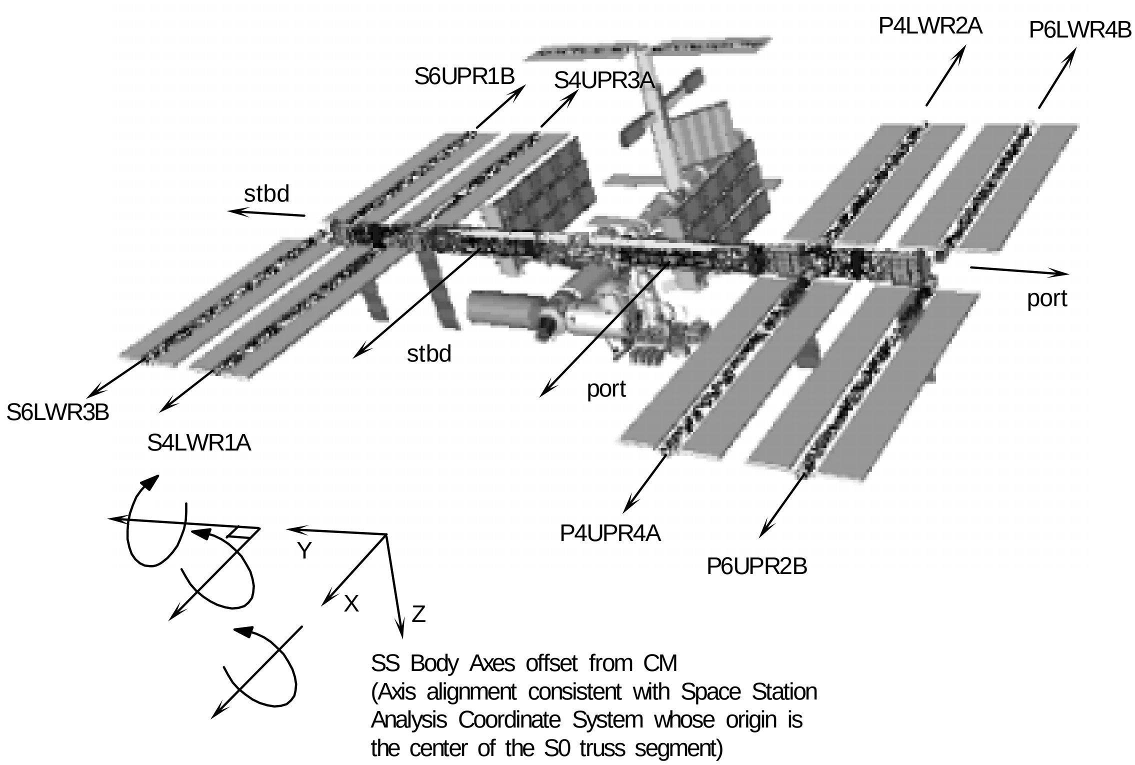
NAME:	Space Shuttle Orbiter Structural Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
DESCRIPTION:	This coordinate system is consistent with NSTS 07700, Volume IV, Attachment 1, ICD–2–19001, Shuttle Orbiter/Cargo Standard Interfaces. All dimensions in inches.
ORIGIN:	The origin is located in the orbiter plane of symmetry at a point 400 inches below the centerline of the payload bay and 236 inches forward of the orbiter nose.
ORIENTATION:	X_O The X–axis is parallel to the longitudinal axis of the payload bay, 400 inches below the centerline of the payload bay. The positive X–axis is toward the tail.
	Z_O The Z–axis is located in the orbiter plane of symmetry, perpendicular to the X–axis. The positive Z–axis is in upward direction in the landing attitude.
	Y_O The positive Y–axis is in the direction of port and completes the rotating right–handed Cartesian system.
SUBSCRIPT:	O

FIGURE 4.0–6 SPACE SHUTTLE ORBITER STRUCTURAL COORDINATE SYSTEM



NAME:	Orbiter Body Axis Coordinate System
ORIGIN:	Orbiter center of mass
ORIENTATION:	X_{BY} The X–axis is parallel to a line in the Orbiter plane of symmetry, parallel to and 1016 centimeters (400 inches) below the payload bay centerline with positive sense toward the nose.
	Z_{BY} The Z–axis is parallel to the Orbiter plane of symmetry and is perpendicular to X_{BY}, positive down with respect to the Orbiter fuselage.
	Y_{BY} The Y–axis completes the right–handed orthogonal system.
CHARACTERISTICS:	Right–handed Cartesian system.
	The Euler sequence that is associated with this system is a yaw, pitch, roll, sequence, where ψ = yaw, θ = pitch, and ϕ = roll or blank. This attitude sequence is yaw, pitch, and roll around the Z_{BY}, Y_{BY}, and X_{BY} axes, respectively.
	L, M, N: Moments about X_{BY}, Y_{BY}, and Z_{BY} axes, respectively.
	p, q, r: Body rates about X_{BY}, Y_{BY}, and Z_{BY} axes, respectively.
	$\dot{p}$, $\dot{q}$, $\dot{r}$: Angular body acceleration about X_{BY}, Y_{BY}, and Z_{BY} axes, respectively.

FIGURE 4.0–7 ORBITER BODY AXES



NAME: Alpha, Beta, and Gamma Angle definitions

DESCRIPTION: The generic ***analysis angles*** α and γ are defined as positive right handed rotations about the y and x axes respectively. The analysis angle β is defined as a positive right handed rotation with its axis of rotation being perpendicular to that of α and rotated by α . The β axis is aligned with the x axis when $\alpha = 0°$. In the figure above, $\alpha = 0°$, $\beta = 0°$ (active side of the arrays facing in –z direction), and $\gamma = +90°$, because the radiators have been rotated 90° about the x axis.

In addition to the generic analysis angles, each joint has its own local reference angle used to command its joint motor. These 12 specific ***joint angles***, labeled in the figure above, are right handed rotations about their individual rotation axes. The joint angles are always identified by their unique subscripts to differentiate them from the generic analysis angles.

ORIENTATION: The α joint angles, α_{stbd} and α_{port}, are positive right handed rotations about the rotation axes pointed outboard from each joint. The 0° position is as shown in the figure, when the normal to the arrays as oriented point in the –z axis direction. The individual joint angle rotation capabilities are 0° to 360° (continuous rotation).

For each β joint angle, a positive β rotation is right handed looking outward along the array from the motor. The 0° position is defined as when the normal to the array face is pointed inboard, parallel to the y axis. Thus, the joint specific target angles represented in the figure are:

FIGURE 4.0–8 ALPHA, BETA, AND GAMMA ANGLE DEFINITIONS

$[\beta_{S4UPR3A}, \beta_{S4LWR1A}, \beta_{S6UPR1B}, \beta_{S6LWR3B}] = [-90^\circ, 90^\circ, -90^\circ, 90^\circ]$,

$[\beta_{P4UPR4A}, \beta_{P4LWR2A}, \beta_{P6UPR2B}, \beta_{P6LWR4B}] = [-90^\circ, 90^\circ, -90^\circ, 90^\circ]$.

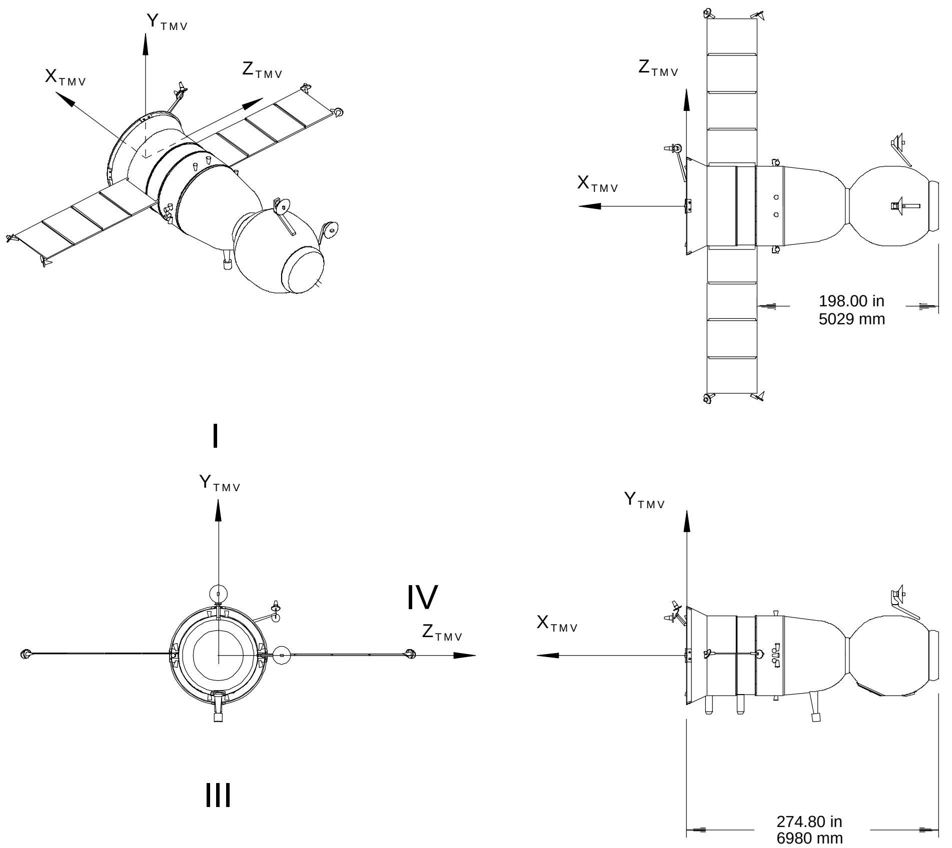
The individual joint angle rotation capabilities are 0° to 360° (continuous rotation).

The γ joint angles, γ_{stbd} and γ_{port}, are positive right handed rotations about the rotation axes pointed in the +x axis direction. The 0° position is defined as when the radiator beams lie in the x–y plane. The individual joint angle rotation capabilities are 0° to ±115° (hardware limit), although the radiator commands are restricted to ±105° (software limit).

TRANSFORMATIONS: Therefore, the following transformations define the relationship between the generic analysis angles and the individual joint angles:

$$\begin{bmatrix}\alpha_{stbd}\\ \alpha_{port}\end{bmatrix} = \begin{bmatrix}1\\ -1\end{bmatrix}\alpha \qquad \begin{bmatrix}\beta_{S4UPR3A}\\ \beta_{S4LWR1A}\\ \beta_{S6UPR1B}\\ \beta_{S6LWR3B}\\ \hline \beta_{P4UPR4A}\\ \beta_{P4LWR2A}\\ \beta_{P6UPR2B}\\ \beta_{P6LWR4B}\end{bmatrix} = \begin{bmatrix}-\beta-90^\circ\\ \beta+90^\circ\\ -\beta-90^\circ\\ \beta+90^\circ\\ \hline \beta-90^\circ\\ -\beta+90^\circ\\ \beta-90^\circ\\ -\beta+90^\circ\end{bmatrix} \qquad \begin{bmatrix}\gamma_{stbd}\\ \gamma_{port}\end{bmatrix} = \begin{bmatrix}1\\ 1\end{bmatrix}\gamma$$

FIGURE 4.0–8 ALPHA, BETA, AND GAMMA ANGLE DEFINITIONS – Continued



NAME: Soyuz Body Axis Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed

ORIGIN: The origin is located at the center of the aft bulkhead

ORIENTATION:

X_{TMV} The X–axis is parallel to the longitudinal axis of the module. The positive X–axis is away from the docking cone.

Y_{TMV} The positive Y–axis is perpendicular to X_{TMV} and its projection passes through the nominal center of the docking antenna. The positive Y–axis is in the direction of the docking antenna.

Z_{TMV} The Z–axis completes the right–handed Cartesian system.

The Euler sequence that is associated with this system is a yaw, pitch, roll, sequence, where ψ = yaw, θ = pitch, and ϕ = roll or blank. This attitude sequence is yaw, pitch, and roll around the Z_{TMV}, Y_{TMV}, and X_{TMV} axes, respectively.

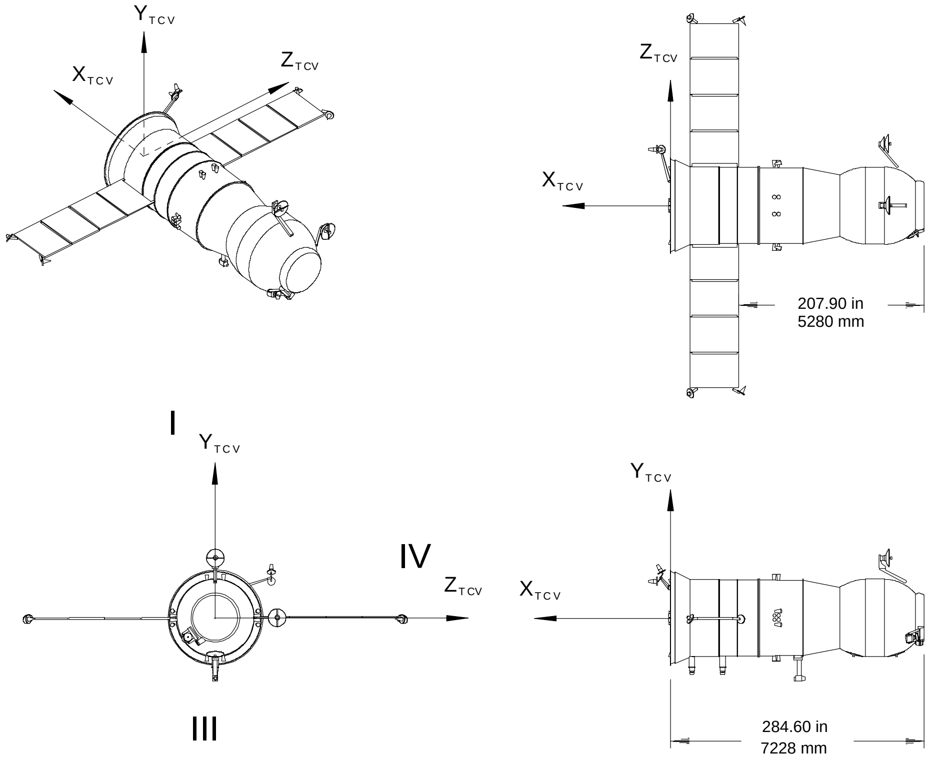
L, M, N: Moments about X_{TMV}, Y_{TMV}, and Z_{TMV} axes, respectively.

p, q, r: Body rates about X_{TMV}, Y_{TMV}, and Z_{TMV} axes, respectively.

$\dot{p}$, $\dot{q}$, $\dot{r}$: Angular body acceleration about X_{TMV}, Y_{TMV}, and Z_{TMV} axes, respectively.

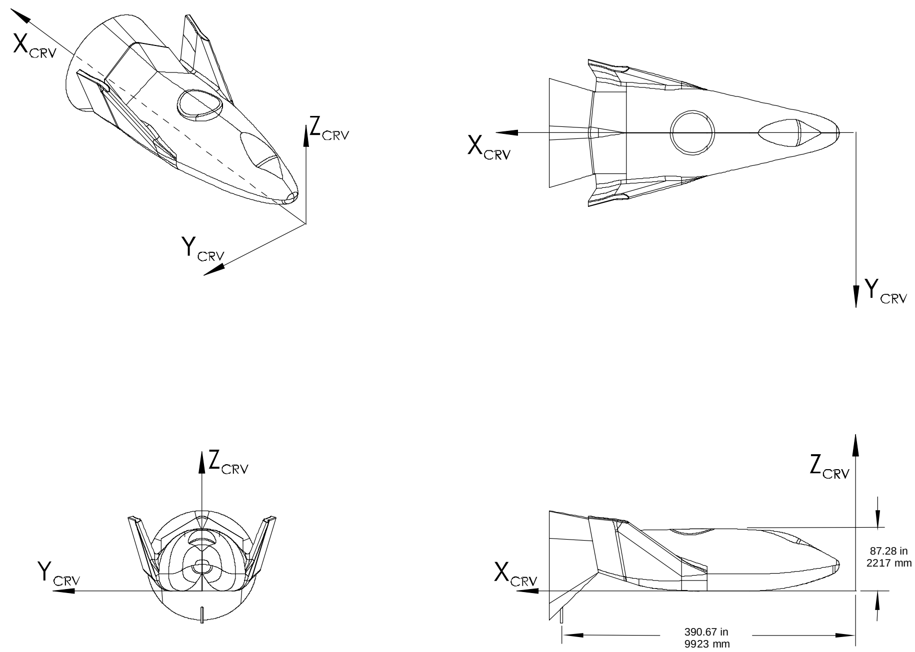
SUBSCRIPT: TMV

FIGURE 4.0–9 SOYUZ TM TRANSPORT MANNED VEHICLE COORDINATE SYSTEM



NAME:	Progress M Body Axis Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located at the center of the aft bulkhead
ORIENTATION:	X_{TCV} The X–axis is parallel to the longitudinal axis of the module. The positive X–axis is away from the docking cone.
	Y_{TCV} The positive Y–axis is perpendicular to X_{TCV} and its projection passes through the nominal center of the docking antenna. The positive Y–axis is in the direction of the docking antenna.
	Z_{TCV} The Z–axis completes the right–handed Cartesian system.
	The Euler sequence that is associated with this system is a yaw, pitch, roll, sequence, where ψ = yaw, θ = pitch, and ϕ = roll or blank. This attitude sequence is yaw, pitch, and roll around the Z_{TCV}, Y_{TCV}, and X_{TCV} axes, respectively.
	L, M, N: Moments about X_{TCV}, Y_{TCV}, and Z_{TCV} axes, respectively.
	p, q, r: Body rates about X_{TCV}, Y_{TCV}, and Z_{TCV} axes, respectively.
	$\dot{p}$, $\dot{q}$, $\dot{r}$: Angular body acceleration about X_{TCV}, Y_{TCV}, and Z_{TCV} axes, respectively.
SUBSCRIPT:	TCV

FIGURE 4.0–10 PROGRESS–M TRANSPORT CARGO VEHICLE COORDINATE SYSTEM



NAME: Crew Return Vehicle Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed

ORIGIN: The origin is located 6” in front of the vehicle nose and flush with the exterior floor.

ORIENTATION: X_{CRV} The X–axis is parallel to the longitudinal axis of the vehicle. The positive X–axis is in the rearward direction.

Z_{CRV} The Z–axis is the direction of the CBM.

Y_{CRV} The positive Y–axis completes the right handed coordinate frame.

The Euler sequence that is associated with this system is a yaw, pitch, roll, sequence, where ψ = yaw, θ = pitch, and ϕ = roll or blank. This attitude sequence is yaw, pitch, and roll around the Z_{CRV}, Y_{CRV}, and X_{CRV} axes, respectively.

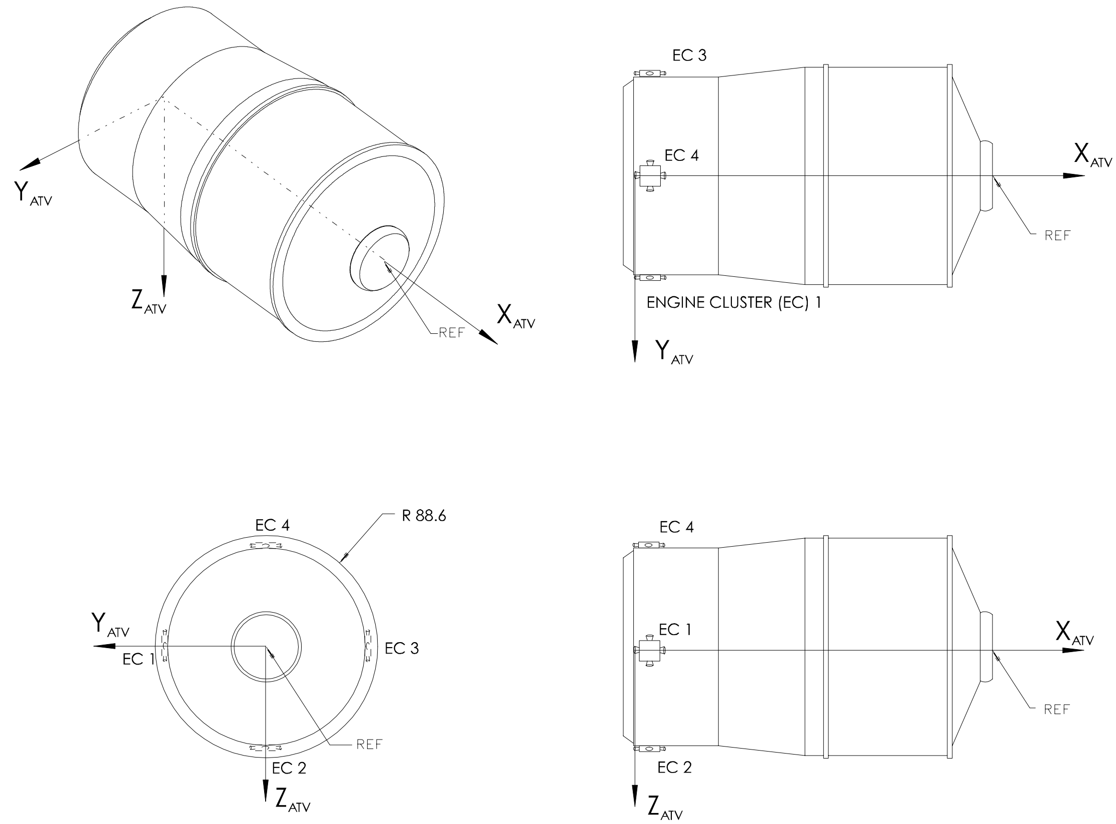
L, M, N: Moments about X_{CRV}, Y_{CRV}, and Z_{CRV} axes, respectively.

p, q, r: Body rates about X_{CRV}, Y_{CRV}, and Z_{CRV} axes, respectively.

$\dot{p}$, $\dot{q}$, $\dot{r}$: Angular body acceleration about X_{CRV}, Y_{CRV}, and Z_{CRV} axes, respectively.

SUBSCRIPT: CRV

FIGURE 4.0–11 CREW RETURN VEHICLE COORDINATE SYSTEM



NAME: Automated Transfer Vehicle

TYPE: Right–Handed Cartesian, Body–Fixed

ORIGIN: The origin is located 100 inches in front of and at the center of the docking mechanism interface.

ORIENTATION: X_{ATV} The X–axis correspnds to the ATV longitudanal axis, with a posative direction from the ATV Spacecraft toward the ATV Cargo Module.

Y_{ATV} The Y–axis is perpendicular to X_{ATV}, with a positive toward the ATV engine cluster 1.

Z_{ATV} The Z–axis completes the right–handed orthogonal system.

The Euler sequence that is associated with this system is a yaw, pitch, roll, sequence, where ψ = yaw, θ = pitch, and ϕ = roll or blank. This attitude sequence is yaw, pitch, and roll around the Z_{ATV}, Y_{ATV}, and X_{ATV} axes, respectively.

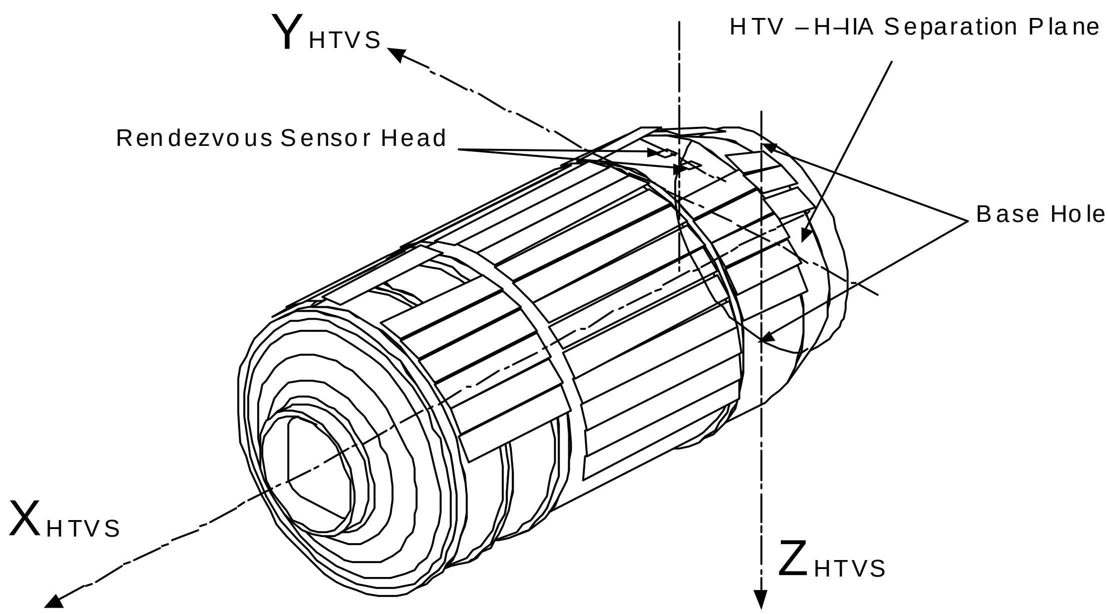
L, M, N: Moments about X_{ATV}, Y_{ATV}, and Z_{ATV} axes, respectively.

p, q, r: Body rates about X_{ATV}, Y_{ATV}, and Z_{ATV} axes, respectively.

$\dot{p}$, $\dot{q}$, $\dot{r}$: Angular body acceleration about X_{ATV}, Y_{ATV}, and Z_{ATV} axes, respectively.

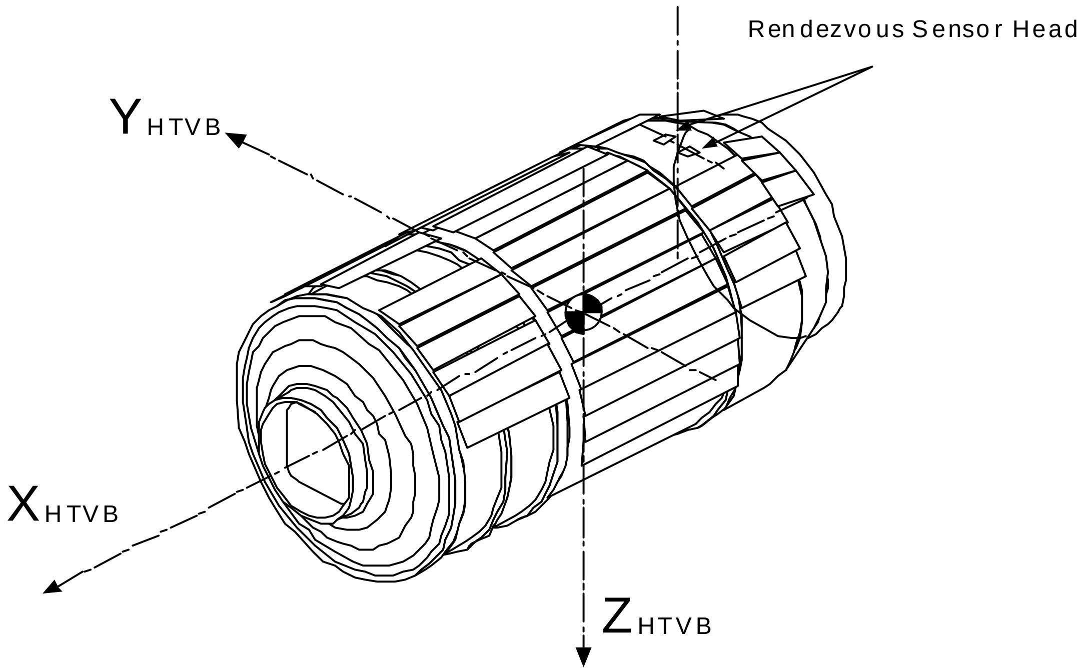
SUBSCRIPT: ATV

FIGURE 4.0–12 AUTOMATED TRANSFER VEHICLE COORDINATE SYSTEM



NAME:	H–II Transfer Vehicle Coordinate System, Mechanical Design Reference
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	X_{HTVS}=0: HTV/Launch Vehicle Separation Plane
	Y_{HTVS}=0: Base Holes on Separation Plane
	Z_{HTVS}=0: Center of Base Holes
ORIENTATION:	X_{HTVS} The X–axis is parallel to the longitudinal axis of the module cluster. The positive X–axis is toward the CBM interface.
	Z_{HTVS} The Z–axis is perpendicular to X_{HTVS} and goes through the two Base Holes on the separation plane. The negative Z–axis is in the direction of the Rendezvous Sensor head side as shown.
	Y_{HTVS} The Y–axis completes the right–handed orthogonal system.
SUBSCRIPT:	HTVS

FIGURE 4.0–13 H–II TRANSFER VEHICLE COORDINATE SYSTEM, MECHANICAL DESIGN REFERENCE



NAME:	H–II Transfer Vehicle Coordinate System, Attitude Reference
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The HTV Center of Mass with respect to the HTV Mechanical Design Reference Coordinate System
ORIENTATION:	X_{HTVB} The X–axis is parallel to the longitudinal axis of the module cluster. The positive X–axis is toward the CBM interface.
	Z_{HTVB} The Z–axis is perpendicular to X_{HTVB} and parallel to the centerline of field of view of Rendezvous Sensor. The negative Z–axis is in the direction of the Rendezvous Sensor head side as shown.
	Y_{HTVB} The Y–axis completes the right–handed orthogonal system.

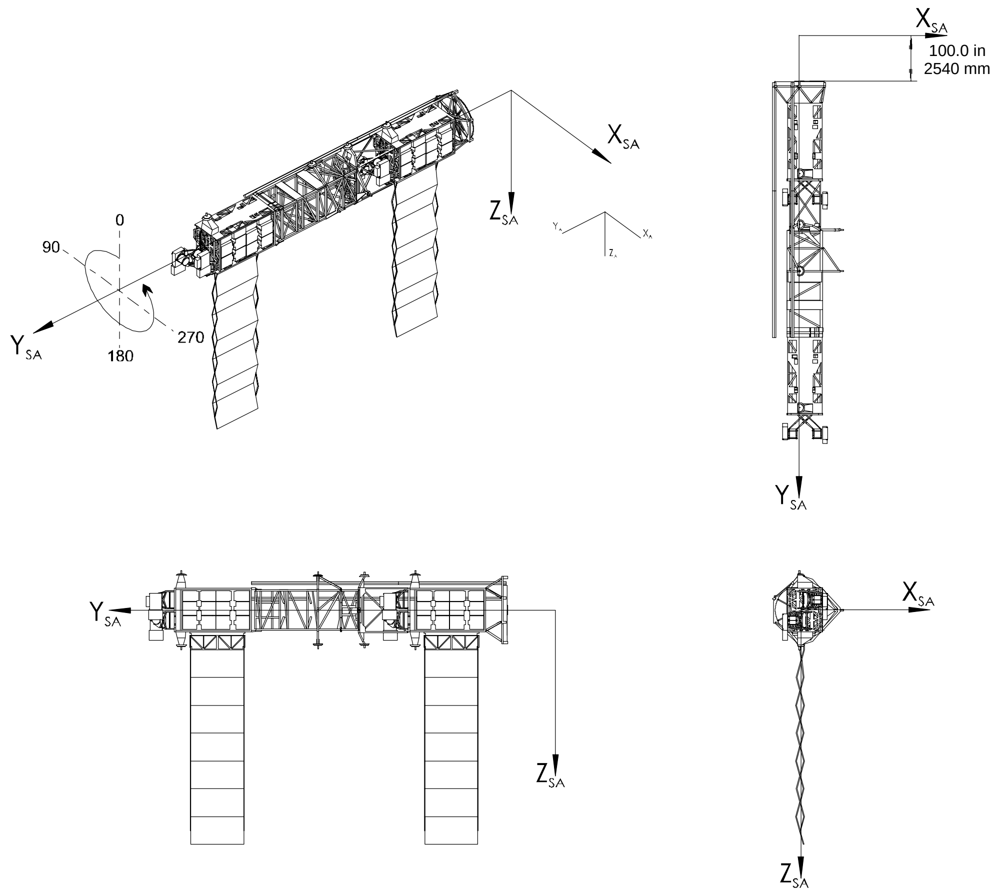
The Euler sequence that is associated with this system is a yaw, pitch, roll, sequence, where ψ = yaw, θ = pitch, and ϕ = roll or bank. This attitude sequence is yaw, pitch, and roll around the Z_{HTVB}, Y_{HTVB}, and X_{HTVB} axes, respectively.

SUBSCRIPT: HTVB

FIGURE 4.0–14 H–II TRANSFER VEHICLE COORDINATE SYSTEM, ATTITUDE REFERENCE

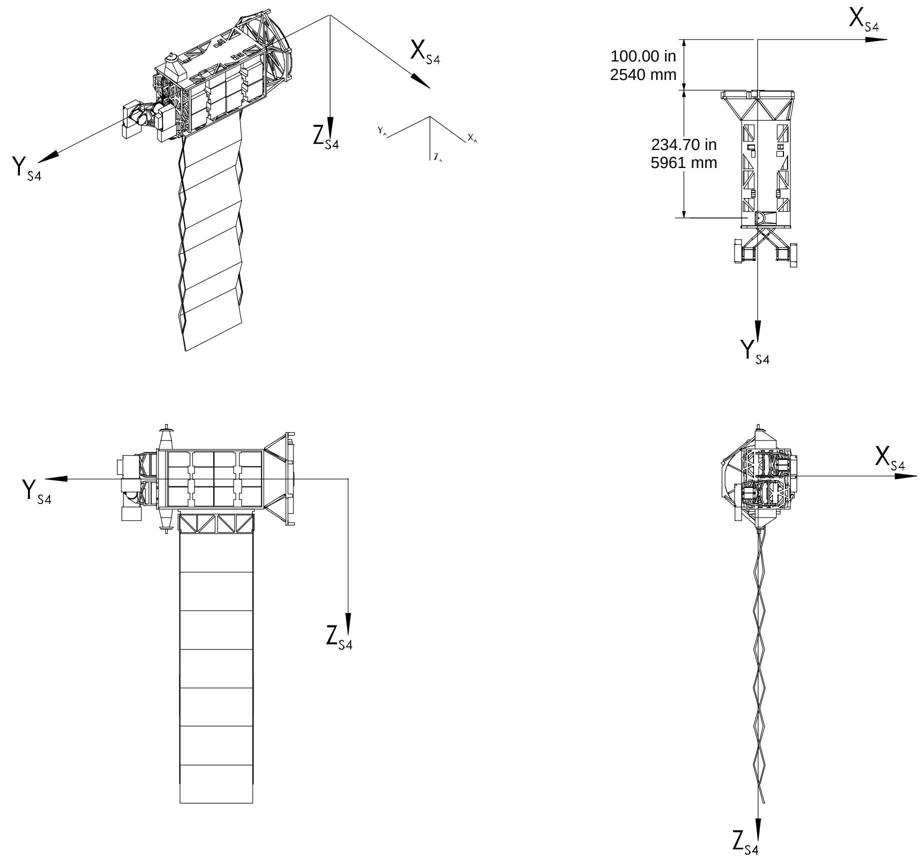
5.0 ARTICULATING AND TRANSVERSE BOOM REFERENCE FRAMES

The coordinate systems outlined in this chapter represent all the articular subelements and transverse boom elements. In addition, the Starboard and Port Solar Power Module elements are defined using the individual subelement definitions as its basis. All dimensions are in inches unless otherwise noted. All drawings include an isometric view, top view, front view and side view moving left to right, top to bottom.



NAME:	Starboard Solar Power Module
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located along the Y_{SA}–axis at a point 100 inches inboard of the S4/S3 interface plane. The S4/S3 interface plane is defined as the outboard face of the outboard Alpha Joint Bulkhead and coincides with the S3 Coordinate system.
ORIENTATION:	Y_{SA} The Y–axis is coincident with the nominal alpha joint axis of rotation, which is defined as perpendicular to the S3/S4 interface plane and located at the center of the Alpha Joint Bulkhead. The positive Y–axis is in the starboard (outboard) direction.
	Z_{SA} The Z–axis is perpendicular to Y_{SA} and parallel to the nominal longitudinal centerline of the integrated equipment assembly radiators, when deployed. The positive Z–axis is in the nadir direction when alpha is equal to zero degrees.
	X_{SA} The positive X–axis is in the ram direction when alpha is equal to zero degrees and completes the right–handed Cartesian system.
SUBSCRIPT:	SA

FIGURE 5.0–1 STARBOARD SOLAR POWER MODULE COORDINATE SYSTEM



NAME: Integrated Truss Segment S4 Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed

ORIGIN: The origin is located along the Y_{S4}–axis at a point 100 inches inboard of the S4/S3 interface plane. The S4/S3 interface plane is defined as the outboard face of the outboard Alpha Joint Bulkhead. NOTE: for S3/S4 element the S3 coordinate frame will be used.

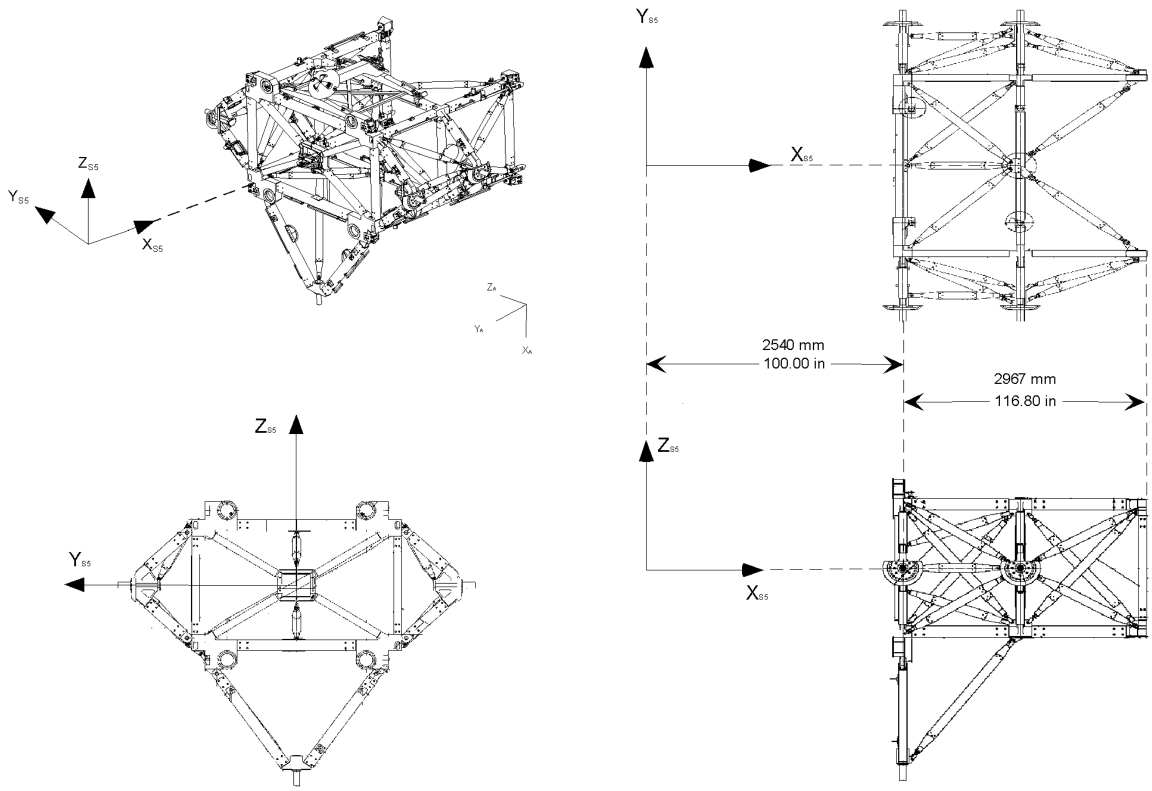
ORIENTATION: Y_{S4} The Y–axis is coincident with the nominal alpha joint axis of rotation, which is defined as perpendicular to the S4/S3 interface plane and located at the center of the Alpha Joint Bulkhead. The positive Y–axis is in the starboard (outboard) direction.

Z_{S4} The Z–axis is perpendicular to Y_{S4} and parallel to the nominal longitudinal centerline of the integrated equipment assembly radiators, when deployed. The positive Z–axis is in the nadir direction when alpha is equal to zero degrees.

X_{S4} The positive X–axis is in the ram direction when alpha is equal to zero degrees and completes the right–handed Cartesian system.

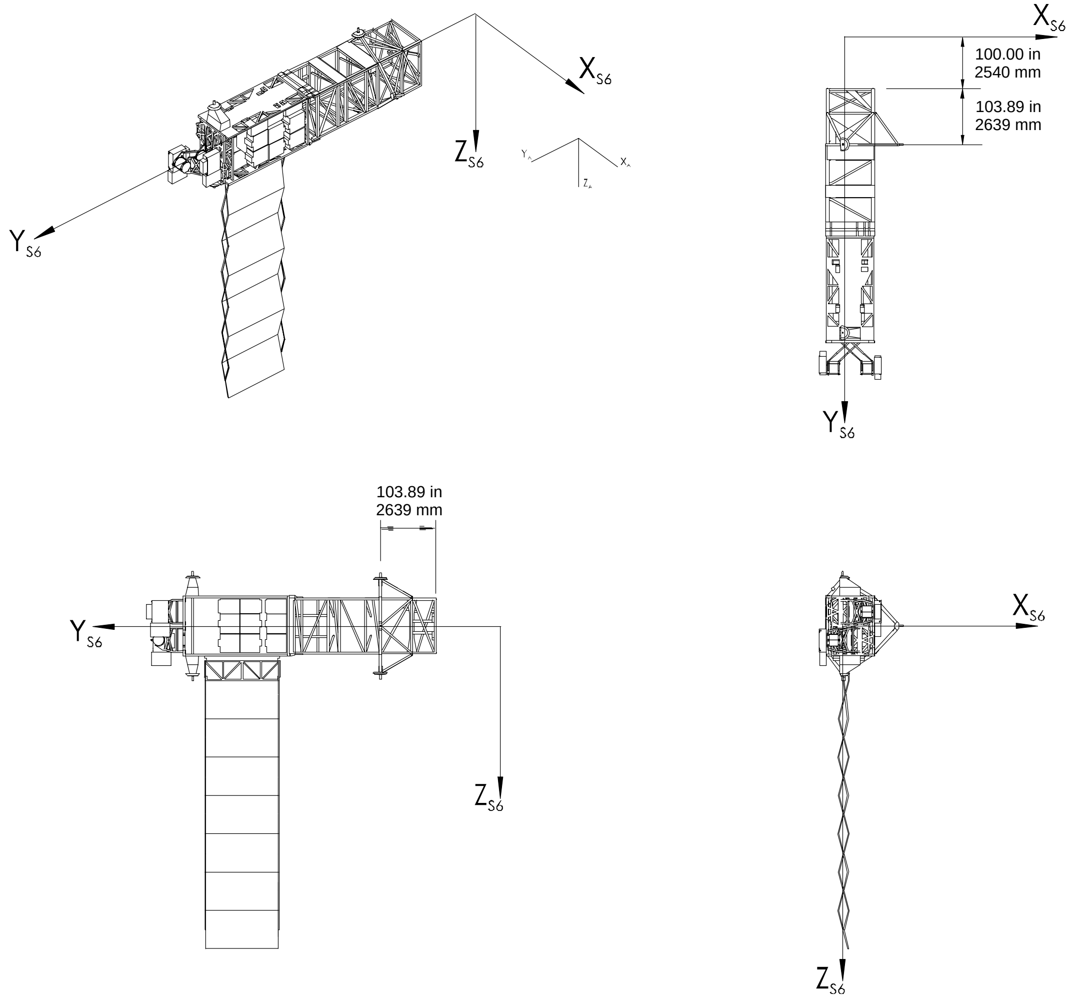
SUBSCRIPT: S4

FIGURE 5.0–2 INTEGRATED TRUSS SEGMENT S4 COORDINATE SYSTEM



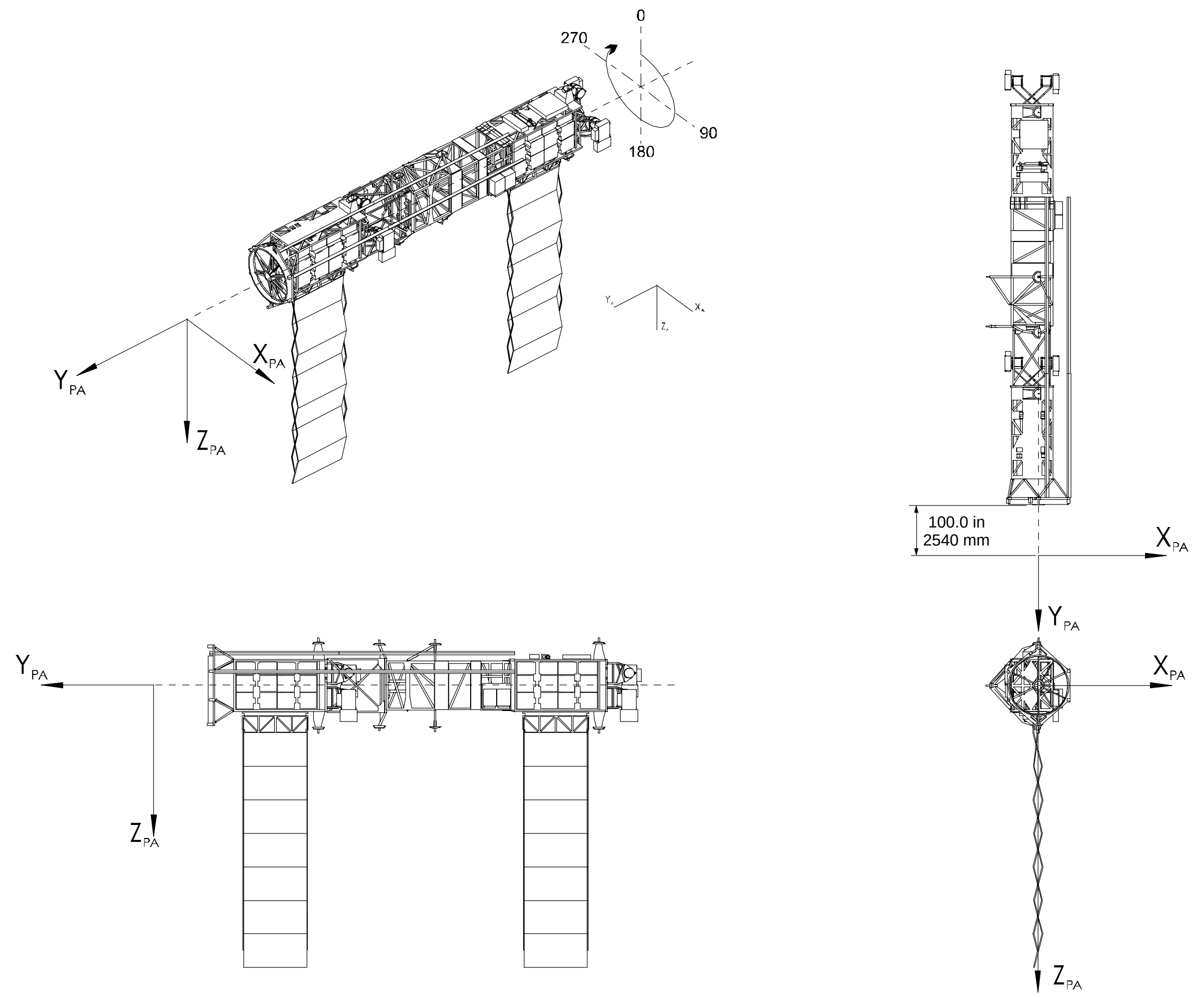
NAME:	Integrated Truss Segment S5 Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located along the structure centerline, 100 inches forward of the primary trunnions, at the elevation of the longitudinal trunnions.
ORIENTATION:	X_{S5} The X–axis is perpendicular to the line formed by connecting the bases of the primary port and starboard trunnions. It runs parallel to the longitudinal extension of S5, through the geometrical center of the bulkhead.
	Y_{S5} The Y–axis is the line formed by connecting the primary port and starboard trunnions, centered at the geometrical center of the bulkhead. The positive Y–axis is starboard.
	Z_{S5} The positive Z–axis is perpendicular to the X_{S5}/ Y_{S5} plane, and completes the right–handed Cartesian system.
SUBSCRIPT:	S5

FIGURE 5.0–3 INTEGRATED TRUSS SEGMENT S5 COORDINATE SYSTEM



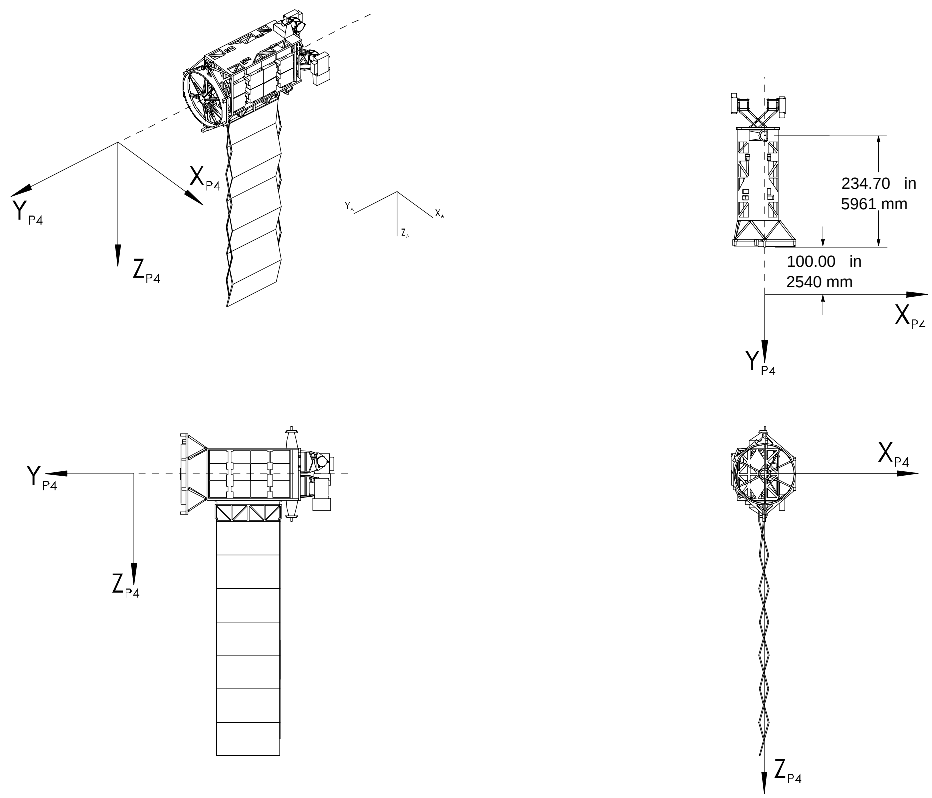
NAME:	Integrated Truss Segment S6 Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located along the Y_{S6}–axis at a point 100 inches inboard of the S6/S5 interface plane. The S6/S5 interface plane is defined as the outermost face of the S6 inboard batten, corner joint assemblies.
ORIENTATION:	Y_{S6} The Y–axis is nominally coincident with the alpha joint axis of rotation. It is defined as perpendicular to Z_{S6}, parallel to the nominal longitudinal extension of S6, and passing through the midpoint of the line connection the centers of the bases of the two inboard trunnions. The positive Y–axis is in the starboard (outboard) direction.
	Z_{S6} The Z–axis is parallel to the line connecting the centers of the bases of the two inboard trunnions. The positive Z–axis is in the nadir direction when alpha is equal to zero degrees.
	X_{S6} The positive X–axis is in the ram direction when alpha is equal to zero degrees and completes the right–handed Cartesian system.
SUBSCRIPT:	S6

FIGURE 5.0–4 INTEGRATED TRUSS SEGMENT S6 COORDINATE SYSTEM



NAME:	Port Solar Power Module Coordinate System
TYPE:	Right–Handed Cartesian
ORIGIN:	The origin is located along the Y_{PA}–axis at a point 100 inches outboard of the P4/P3 interface plane. The P4/P3 interface plane is defined as the outboard face of the outboard Alpha Joint Bulkhead and coincides with the P3 Coordinate system.
ORIENTATION:	Y_{PA} The Y–axis is coincident with the nominal alpha joint axis of rotation, which is defined as perpendicular to the P3/P4 interface plane and located at the center of the Alpha Joint Bulkhead. The positive Y–axis is in the starboard (inboard) direction.
	Z_{PA} The Z–axis is perpendicular to Y_{PA} and parallel to the nominal longitudinal centerline of the integrated equipment assembly radiators, when deployed. The positive Z–axis is in the nadir direction when alpha is equal to zero degrees.
	X_{PA} The positive X–axis is in the ram direction when alpha is equal to zero degrees and completes the right–handed Cartesian system.
SUBSCRIPT:	PA

FIGURE 5.0–5 PORT SOLAR POWER MODULE COORDINATE SYSTEM



NAME: Integrated Truss Segment P4 Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed

ORIGIN: The origin is located along the Y_{P4}–axis at a point 100 inches inboard of the P4/P3 interface plane. The P4/P3 interface plane is defined as the outboard face of the outboard Alpha Joint Bulkhead. NOTE: For P3/P4 coordinate frame use the P3 frame.

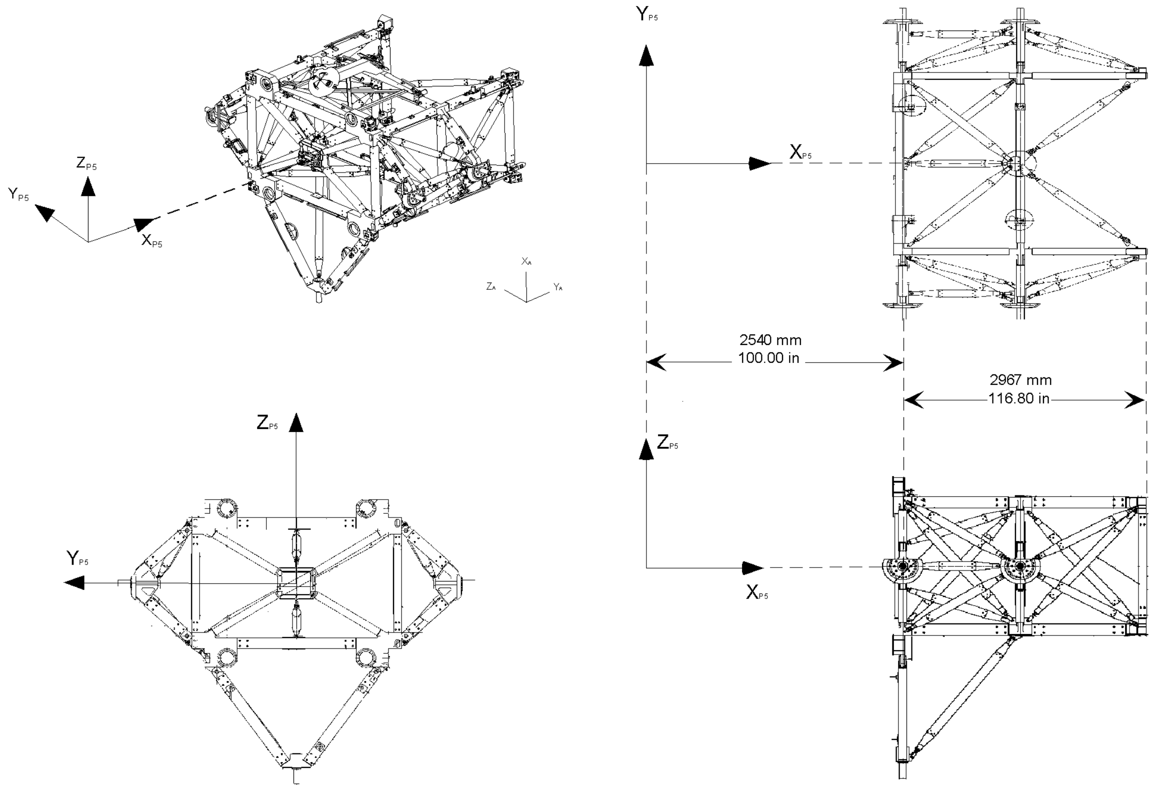
ORIENTATION: Y_{P4} The Y–axis is coincident with the nominal alpha joint axis of rotation, which is defined as perpendicular to the P4/P3 interface plane and located at the center of the Alpha Joint Bulkhead. The positive Y–axis is in the starboard (inboard) direction.

Z_{P4} The Z–axis is perpendicular to Y_{P4} and parallel to the nominal longitudinal centerline of the integrated equipment assembly radiators, when deployed. The positive Z–axis is in the nadir direction when alpha is equal to zero degrees.

X_{P4} The positive X–axis is in the ram direction when alpha is equal to zero degrees and completes the right–handed Cartesian system.

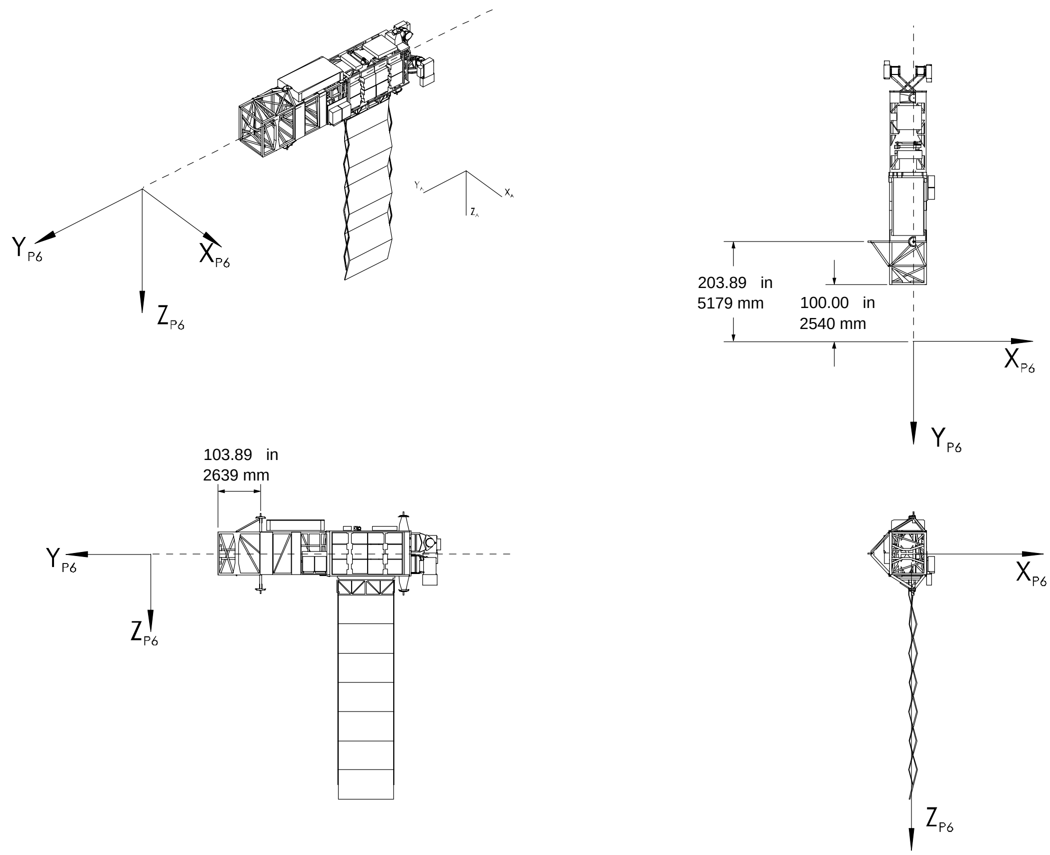
SUBSCRIPT: P4

FIGURE 5.0–6 INTEGRATED TRUSS SEGMENT P4 COORDINATE SYSTEM



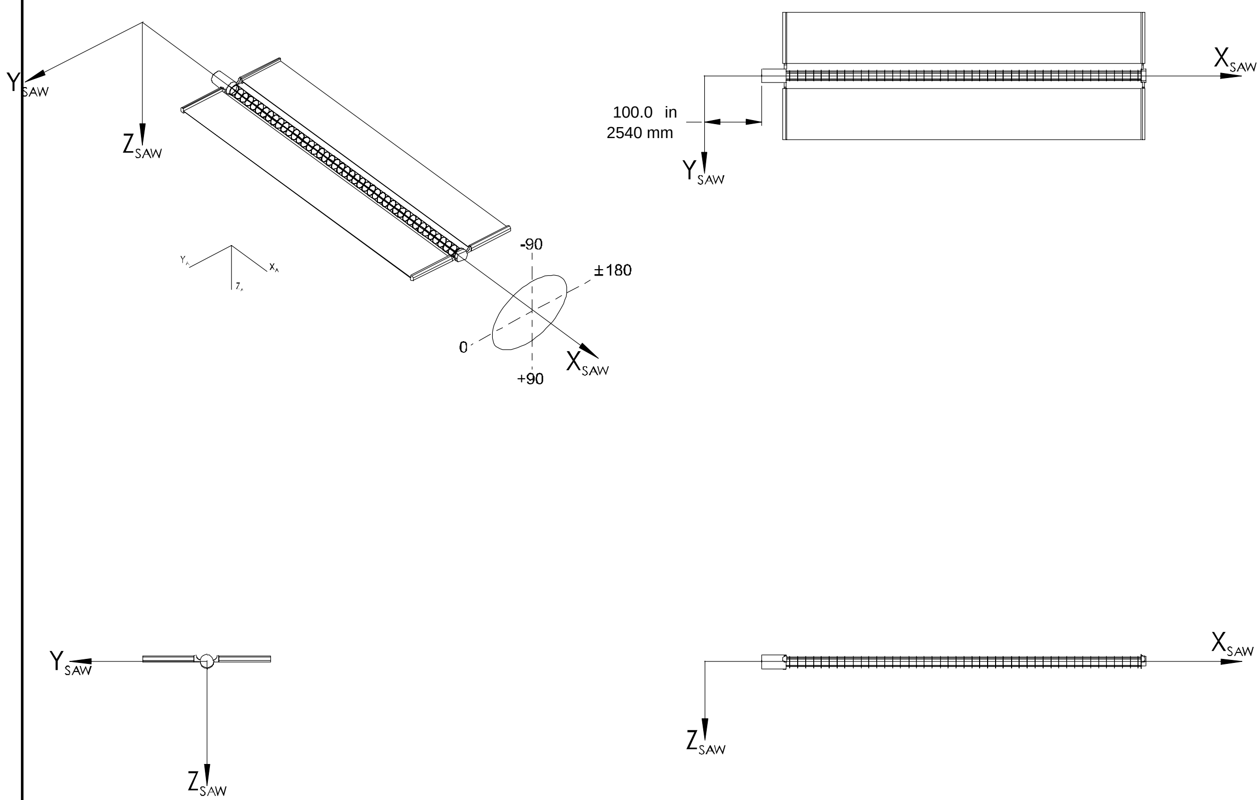
NAME:	Integrated Truss Segment P5 Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located along the structure centerline, 100 inches forward of the primary trunnions, at the elevation of the longitudinal trunnions.
ORIENTATION:	X_{P5} The X–axis is perpendicular to the line formed by connecting the bases of the primary port and starboard trunnions. It runs parallel to the longitudinal extension of P5, through the geometrical center of the bulkhead.
	Y_{P5} The Y–axis is the line formed by connecting the primary port and starboard trunnions, centered at the geometrical center of the bulkhead. The positive Y–axis is starboard.
	Z_{P5} The positive Z–axis is perpendicular to the X_{P5}/ Y_{P5} plane, and completes the right–handed Cartesian system.
SUBSCRIPT:	P5

FIGURE 5.0–7 INTEGRATED TRUSS SEGMENT P5 COORDINATE SYSTEM



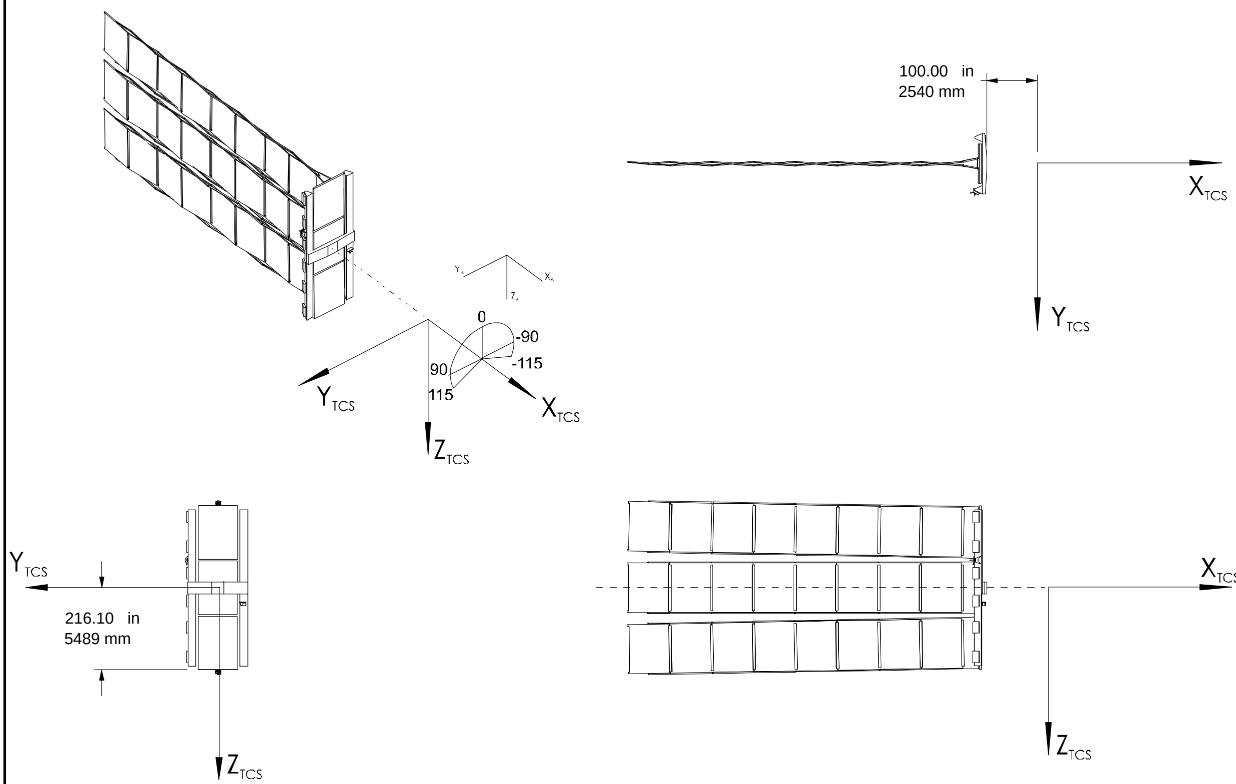
NAME:	Integrated Truss Segment P6 Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located along the Y_{P6}–axis at a point 100 inches inboard of the P6/P5 interface plane. The P6/P5 interface plane is defined as the outermost face of the S6 inboard batten, corner joint assemblies.
ORIENTATION:	Y_{P6} The Y–axis is nominally coincident with the alpha joint axis of rotation. It is defined as perpendicular to Z_{P6}, parallel to the nominal longitudinal extension of P6, and passing through the midpoint of the line connection the centers of the bases of the two inboard trunnions. The positive Y–axis is in the starboard (inboard) direction.
	Z_{P6} The Z–axis is parallel to the line connecting the centers of the bases of the two inboard trunnions. The positive Z–axis is in the nadir direction when alpha is equal to zero degrees.
	X_{P6} The positive X–axis is in the ram direction when alpha is equal to zero degrees and completes the right–handed Cartesian system.
SUBSCRIPT:	P6

FIGURE 5.0–8 INTEGRATED TRUSS SEGMENT P6 COORDINATE SYSTEM



NAME:	Solar Array Wing Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located on the X–axis at a point 100 inches aft of the mast canister platform/beta gimbal interface plane. The mast canister platform/beta gimbal interface plane is defined as the outermost face of the beta canister as shown above. See figure 4.0–8 for a complete definition of beta angles.
DESCRIPTION:	This coordinate system is fixed to the Solar Array panels deployed as a wing, not to the beta gimbal which rotates the wing.
ORIENTATION:	X_{SAW} The X–axis is coincident with the beta joint axis of rotation. The positive X–axis is toward the outer end of the array.
	Y_{SAW} The Y–axis completes the Right–Handed Cartesian system.
	Z_{SAW} The Z–axis is perpendicular to the X axis and normal to the nominal plane of the array wing. The Z axis is positive toward the Anti–Sun Facing (Back) side of the wing.
SUBSCRIPT:	SAW

FIGURE 5.0–9 SOLAR ARRAY WING COORDINATE SYSTEM



NAME: Thermal Control System Radiator Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed

ORIGIN: The origin is located along the X–axis at a point 100 inches inboard of the thermal radiator rotational joint Y–Z interface plane. This interface plane is defined as the attach surface of the Torque Box assembly (shown above) to the TRRJ located on the ITA (not shown).

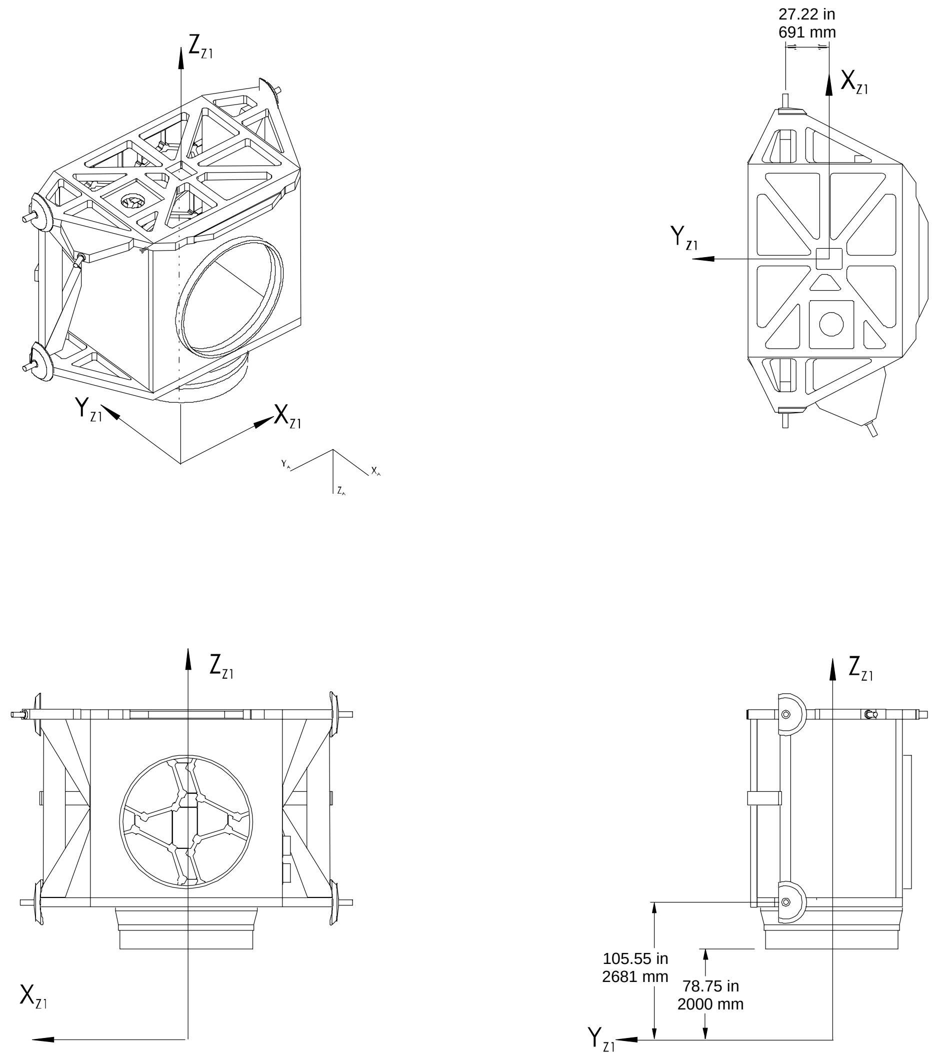
ORIENTATION: X_{TCS} The X–axis is coincident with the gamma joint nominal axis of rotation. The positive X–axis is toward the +X ISS Analytical Reference frame (i.e., away from the Thermal Control System (TCS) radiators).

Y_{TCS} The Y–axis is normal to the nominal plane of the deployed radiator array. The Y–axis is positive in the starboard direction when gamma is equal to zero.

Z_{TCS} The positive Z–axis is in the nadir direction when gamma is equal to zero and completes the right–handed Cartesian system.

SUBSCRIPT: TCS

FIGURE 5.0–10 THERMAL CONTROL SYSTEM RADIATOR COORDINATE SYSTEM



NAME: Integrated Truss Segment Z1 Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed

ORIGIN: The origin is located along the geometric center of the Z1 CBM 79.0 inches from the CBM flange. The XZ plane is parellel to the plane formed by the centerline of the bases of the four trunnions.

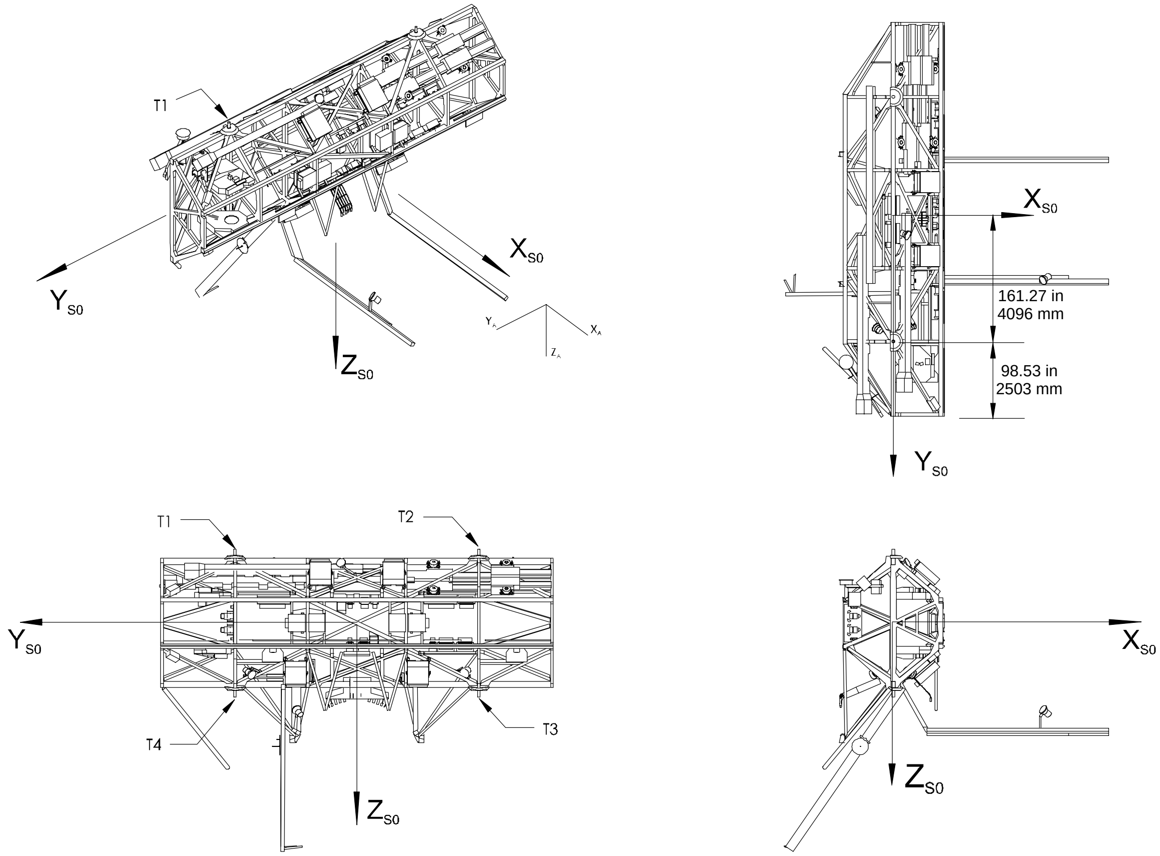
ORIENTATION: X_{Z1} The X–axis is parallel to the trunnion pin plane .

Y_{Z1} The Y–axis completes the right–handed Cartesian system.

Z_{Z1} The Z–axis is collinear with the centerline of the CBM. The positive Z–axis is toward the support structure and

SUBSCRIPT: Z1

FIGURE 5.0–11 INTEGRATED TRUSS SEGMENT Z1 COORDINATE SYSTEM



NAME: Integrated Truss Segment S0 Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed

DESCRIPTION: This coordinate system defines the origin, orientation, and sense of the Space Station Analysis Coordinate System.

ORIGIN: The YZ plane nominally contains the centerline of all four trunnion pins. The origin is defined as the intersection of two diagonal lines connecting the centers of the bases of opposite trunnion pins, running T1 to T3 and from T2 to T4.

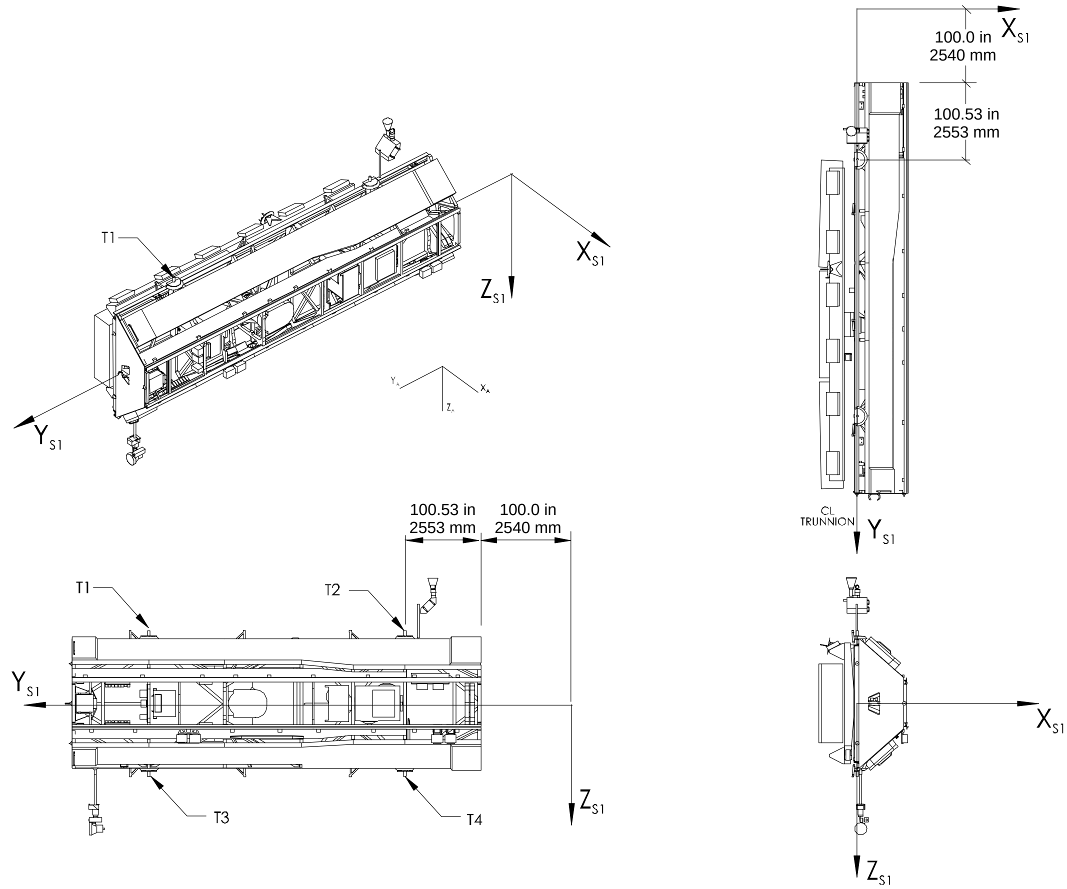
ORIENTATION: X_{S0} The X–axis is parallel to the vector cross–product of the Y–axis with the line from the center of the base trunnion pin T2 to the center of the base trunnion pin T3, and is positive forward.

Y_{S0} The Y–axis is parallel with the line from the center of the base of trunnion pin T2 to the center of the base of trunnion pin T1. The positive Y–axis is toward starboard.

Z_{S0} The Z–axis completes the right–handed Cartesian system.

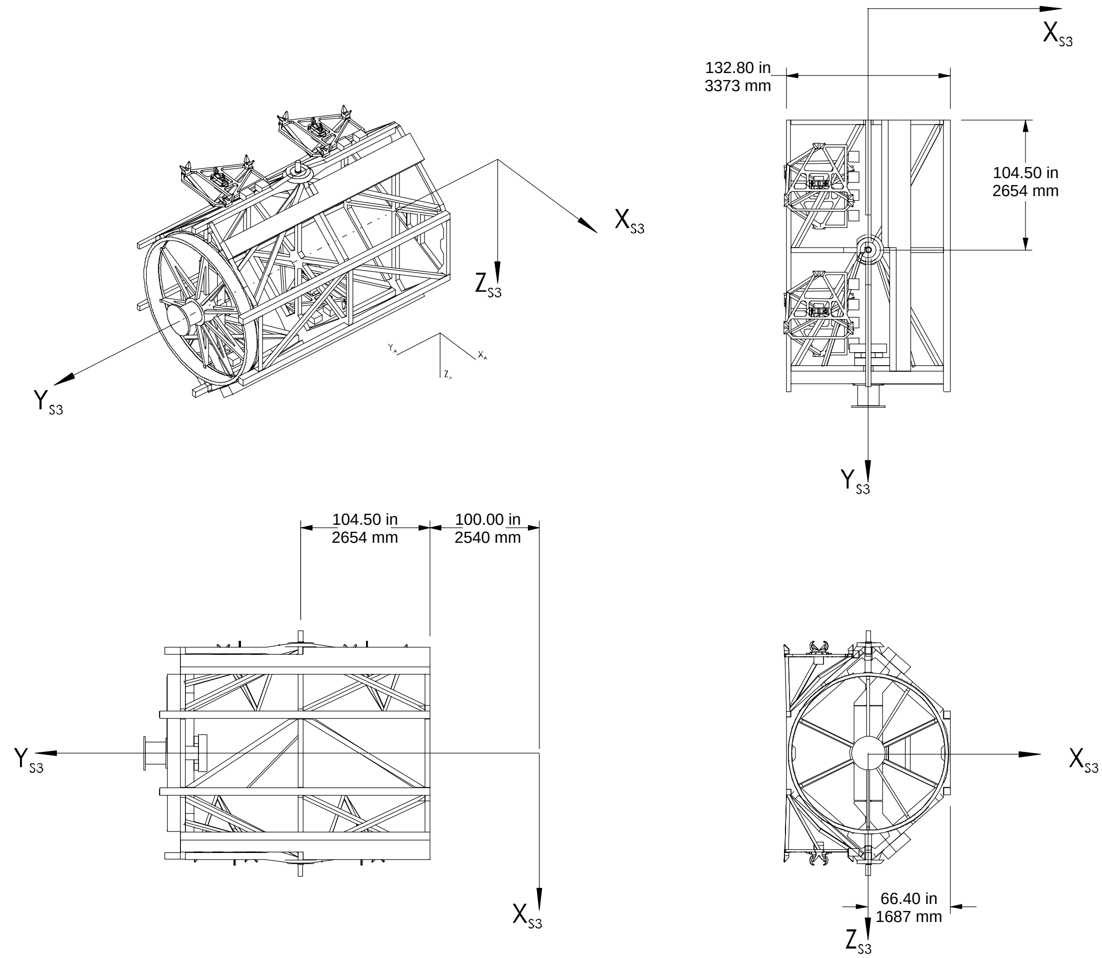
SUBSCRIPT: S0

FIGURE 5.0–12 INTEGRATED TRUSS SEGMENT S0 COORDINATE SYSTEM



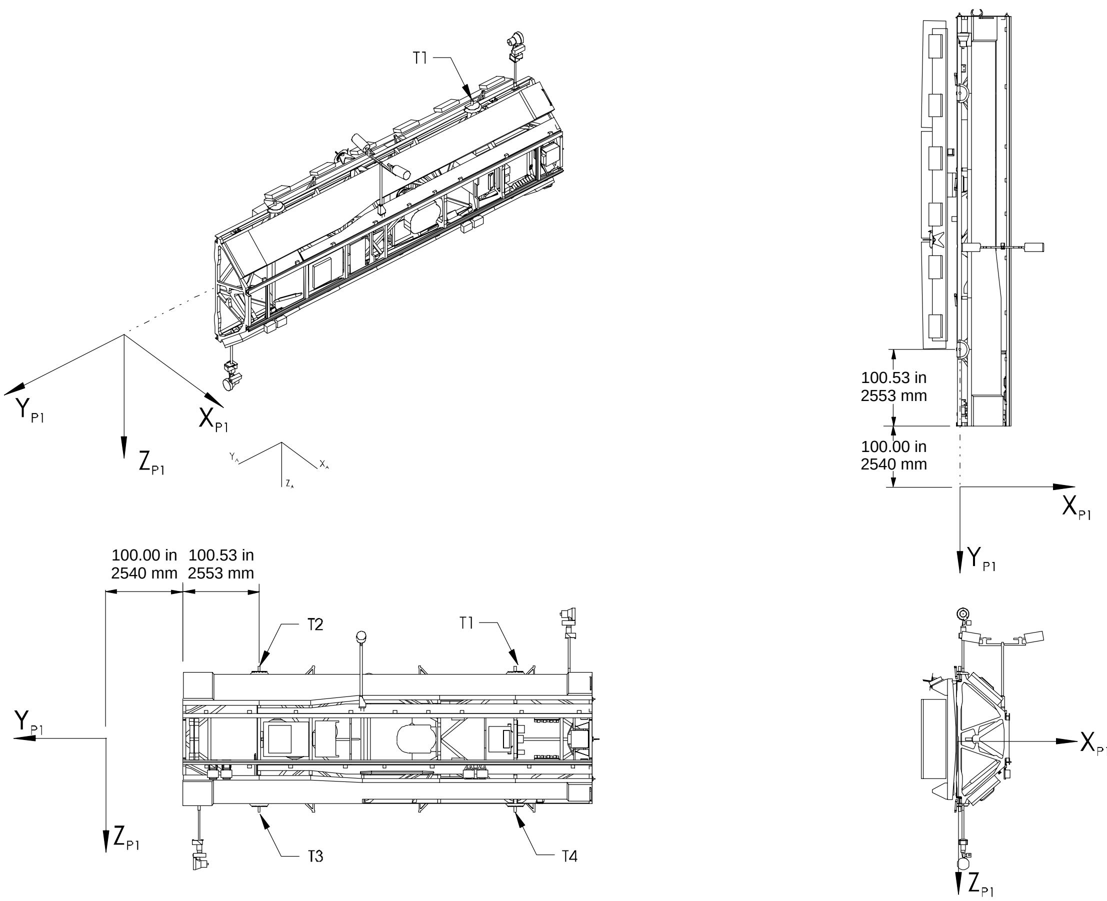
NAME:	Integrated Truss Segment S1 Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located at a point 100 inches from the outer face of the S1 ITS bulkhead that interfaces with the S0 ITS. The YZ plane nominally contains the centerline of all four trunnion pins. The origin is defined as the point 200.53 inches toward port along the Y–axis measured from the line connecting the centers of the base of trunnion pins T2 and T3.
ORIENTATION:	X_{S1} The X–axis is parallel to the vector cross–product of the Y–axis with the line from the center of the base of trunnion pin T2 to the center of the base of trunnion pin T3, and is positive forward.
	Y_{S1} The Y–axis is parallel with the line from the center of the base of trunnion pin T2 to the center of the base of trunnion pin T1, and passes through the midpoint of the line connection the centers of the bases of trunnion pins T2 and T3. The positive Y–axis is toward starboard.
	Z_{S1} The Z–axis completes the right–handed Cartesian system.
SUBSCRIPT:	S1

FIGURE 5.0–13 INTEGRATED TRUSS SEGMENT S1 COORDINATE SYSTEM



NAME:	Integrated Truss Segment S3 Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located at a point 100 inches from the outer face of the S3 ITS bulkhead that interfaces with the S1 ITS. This frame will also be used for the combined S3/S4 element.
ORIENTATION:	X_{S3} The X–axis is parallel to the vector cross–product of the Y–axis with the line between the centers of the bases of the two trunnion pins, and positive forward.
	Y_{S3} The Y–axis is coincident with the alpha joint rotational axis. The positive Y–axis is toward starboard.
	Z_{S3} The Z–axis completes the right–handed Cartesian system.
SUBSCRIPT:	S3

FIGURE 5.0–14 INTEGRATED TRUSS SEGMENT S3 COORDINATE SYSTEM



NAME: Integrated Truss Segment P1 Coordinate System

TYPE: Rotating Right–Handed Cartesian, Body–Fixed

ORIGIN: The origin is located at a point 100 inches from the outer face of the P1 ITS bulkhead that interfaces with the S0 ITS. The YZ plane nominally contains the centerline of all four trunnion pins. The origin is defined as the point 200.53 inches toward port along the Y–axis measured from the line connecting the centers of the base of trunnion pins T2 and T3.

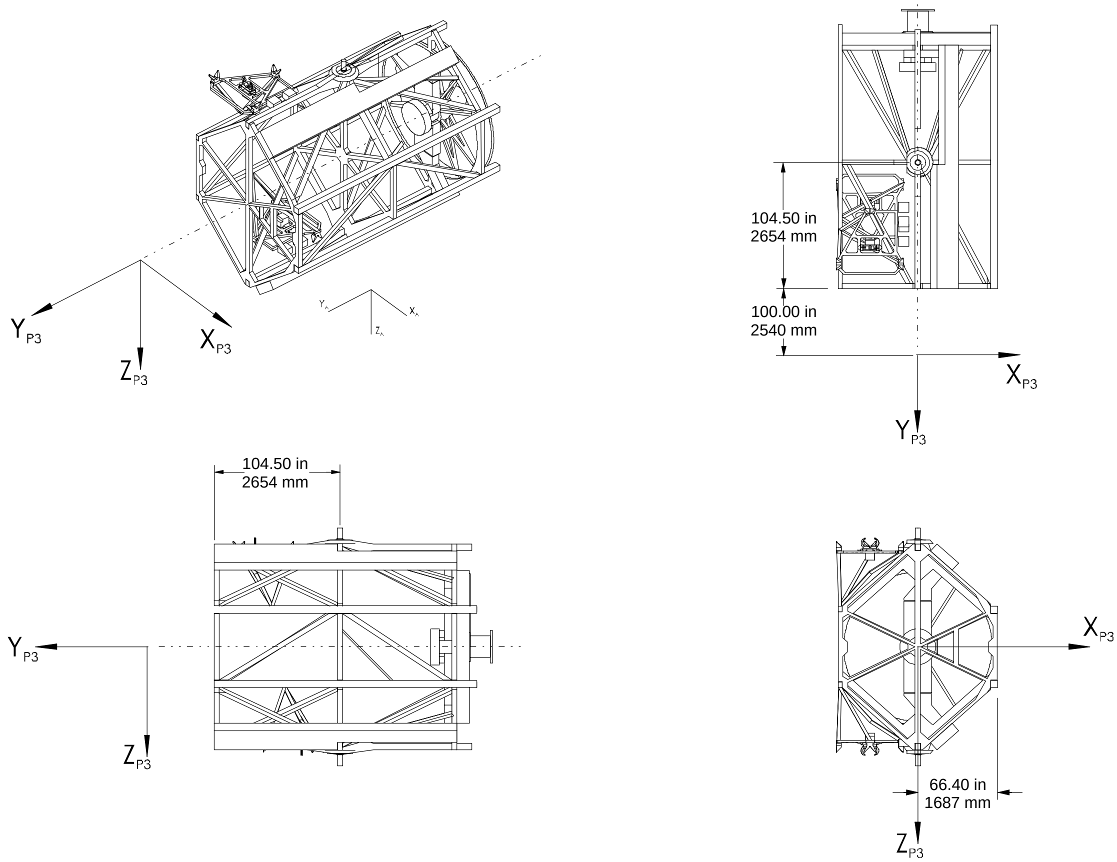
ORIENTATION: X_{P1} The X–axis is parallel to the vector cross–product of the Y–axis with the line from the center of the base of trunnion pin T2 to the center of the base of trunnion pin T3, and is positive forward.

Y_{P1} The Y–axis is parallel with the line from the center of the base of trunnion pin T2 to the center of the base of trunnion pin T1, and passes through the midpoint of the line connection the centers of the bases of trunnion pins T2 and T3. The positive Y–axis is toward starboard.

Z_{P1} The Z–axis completes the right–handed Cartesian system.

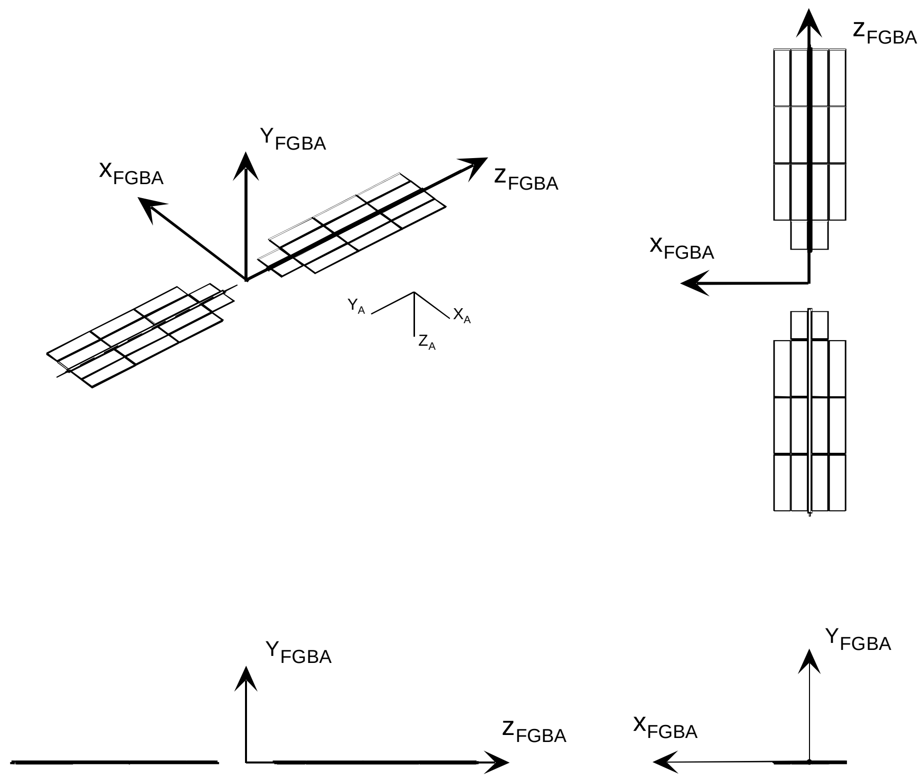
SUBSCRIPT: P1

FIGURE 5.0–15 INTEGRATED TRUSS SEGMENT P1 COORDINATE SYSTEM



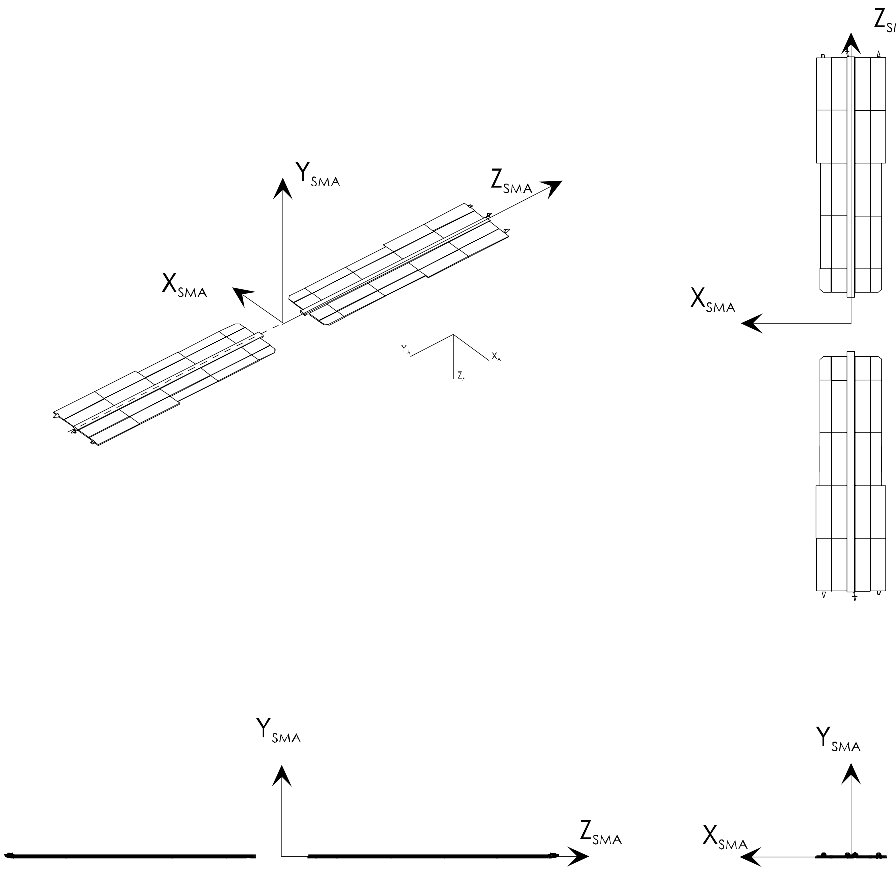
NAME:	Integrated Truss Segment P3 Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located at a point 100 inches from the outer face of the P3 ITS bulkhead that interfaces with the P1 ITS. This frame will also be used for the P3/P4 element.
ORIENTATION:	X_{P3} The X–axis is parallel to the vector cross–product of the Y–axis with the line between the centers of the bases of the two trunnion pins, and positive forward.
	Y_{P3} The Y–axis is coincident with the alpha joint rotational axis. The positive Y–axis is toward starboard.
	Z_{P3} The Z–axis completes the right–handed Cartesian system.
SUBSCRIPT:	P3

FIGURE 5.0–16 INTEGRATED TRUSS SEGMENT P3 COORDINATE SYSTEM



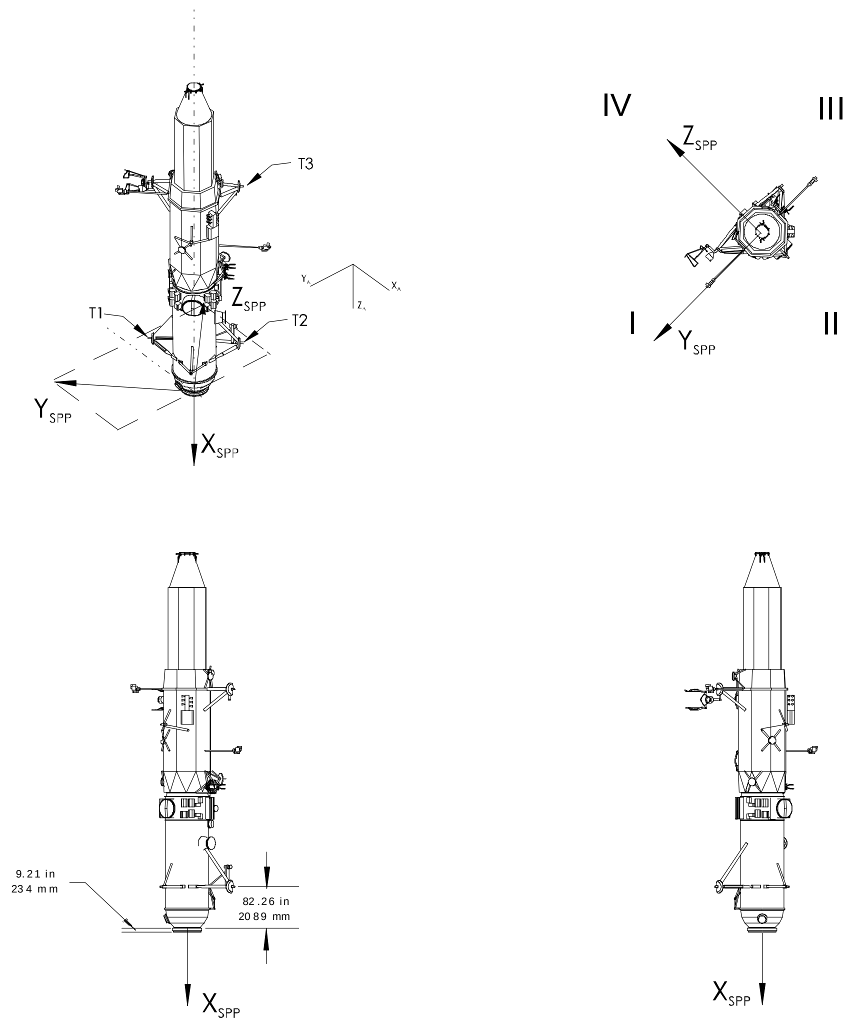
NAME:	FGB Solar Arrays
TYPE:	Right–Handed Cartesian, Body–Fixed
DESCRIPTION:	This coordinate system is aligned as shown with the Space Station Analysis Coordinate System at solar noon when the Space Station is in the LVLH flight orientation.
ORIGIN:	The origin is located along the Z_{FGBA}–axis at a point 58.071 inches inboard of the interface of the starboard FGB Solar Panel.
ORIENTATION:	Z_{FGBA} The Z–axis is coincident with the FGB array axis of rotation, which is along the longitudanal centerline of the array. The positive Z–axis is in the port (outboard) direction.
	X_{FGBA} The X–axis is parallel to X LVLH flight orientation at orbital noon. The positive X–axis is in the –V.
	Y_{FGBA} The Y–axis completes the right–handed cartesian system
SUBSCRIPT:	FGBA

FIGURE 5.0–17 FGB ARRAYS COORDINATE SYSTEM



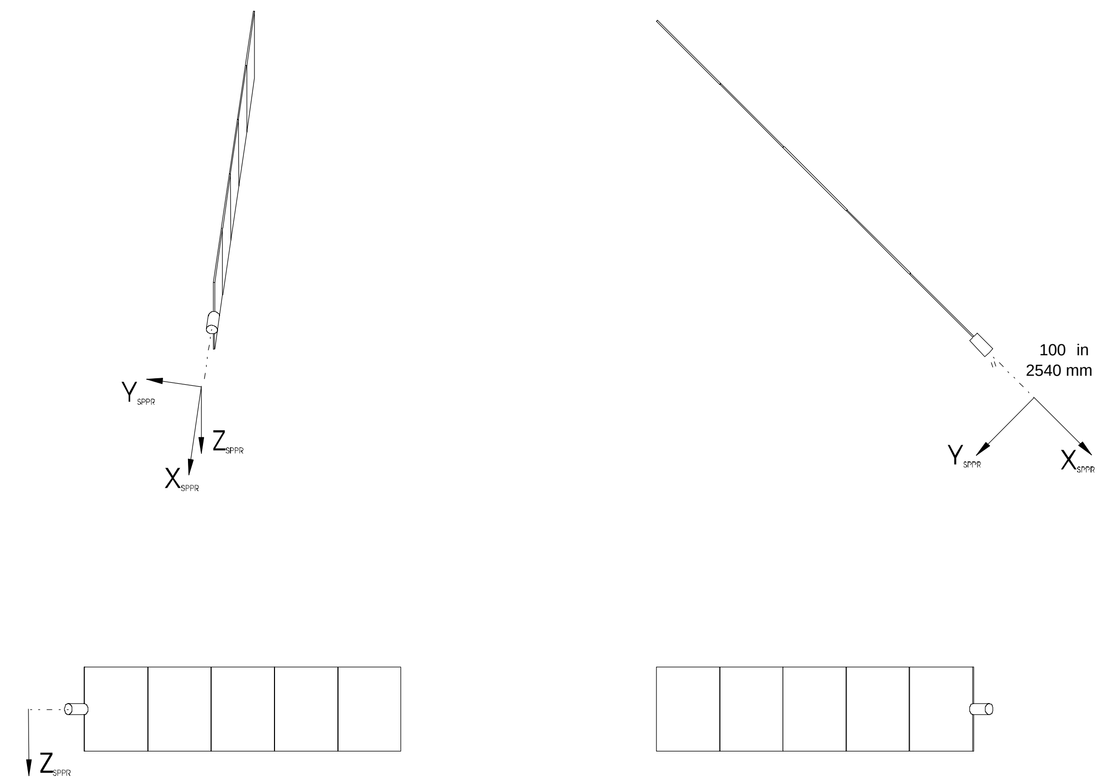
NAME:	SM Solar Arrays
TYPE:	Right–Handed Cartesian, Body–Fixed
DESCRIPTION:	This coordinate system is aligned as shown with the Space Station Analysis Coordinate System at solar noon when the Space Station is in the LVLH flight orientation.
ORIGIN:	The origin is located along the Z_{SMA}–axis at a point 59.055 inches inboard of the interface plane of the starboard SM Solar Panel.
ORIENTATION:	Z_{SMA} The Z–axis is coincident with the SM array axis of rotation, which is along the longitudanal centerline of the array. The positive Z–axis is in the port (outboard) direction.
	X_{SMA} The X–axis completes the right–handed cartesian system.
	Y_{SMA} The Y–axis is perpendicular to the Z–axis and normal to the nominal plane of the array. The Y–axis is positive toward the anti–sun facing (back) side of the array.
SUBSCRIPT:	SMA

FIGURE 5.0–18 SERVICE MODULE ARRAYS COORDINATE SYSTEM



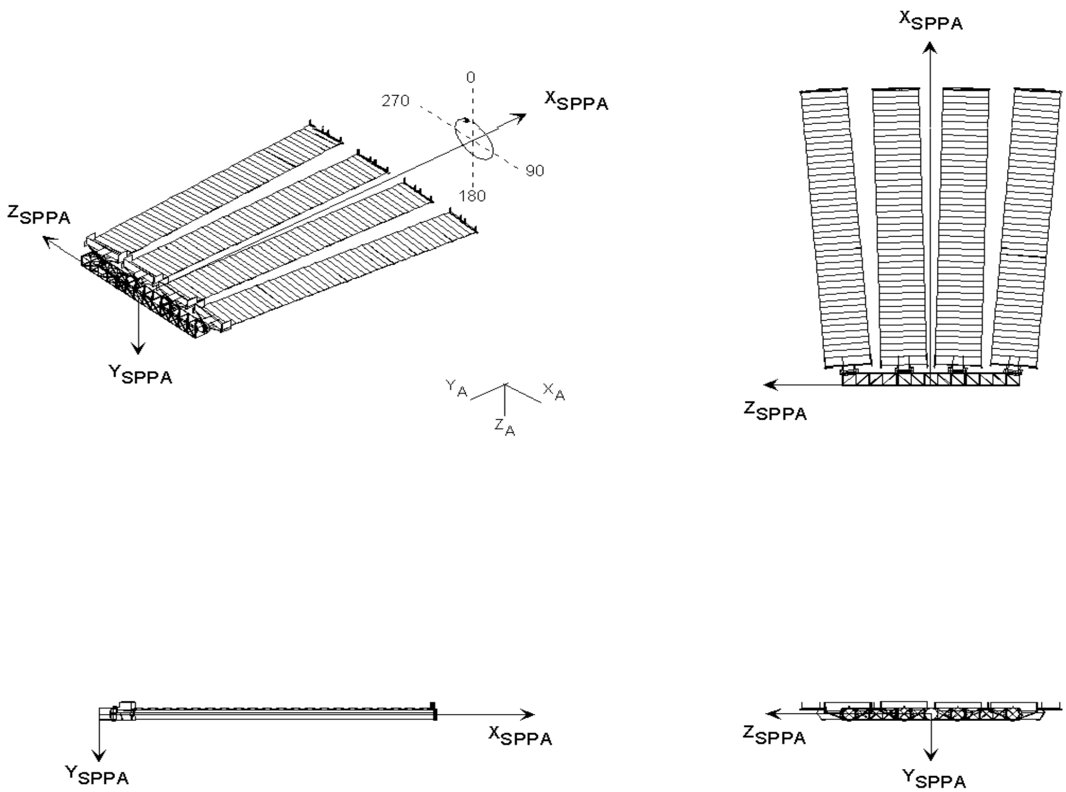
NAME:	Solar Power Platform (SPP) Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located at the center of the SPP/SM bulkhead interface.
ORIENTATION:	X_{SPP} The X–axis is parallel to the line from the center of the base trunnion pin T3 to the center of the base trunnion pin T2, and is positive as shown.
	Y_{SPP} The Y–axis is completes the right–handed Cartesian system.
	Z_{SPP} The Z–axis is parallel to the vector cross–product of the lines between two pairs of trunnions: from the center of the base of trunnion pin T2 to the center of the base of trunnion T1, and from the center of the base of trunnion pin T2 to the center of the base of trunnion pin T3, and is positive as shown.
SUBSCRIPT:	SPP

FIGURE 5.0–19 SCIENCE POWER PLATFORM COORDINATE SYSTEM



NAME:	SPP Radiator Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
DESCRIPTION:	This coordinate system is defined using the mechanical constraints of the SPP Radiator Rotary Joint as well as the Space Station LVLH flight orientation.
ORIGIN:	The origin is located along the X–axis at a point 100 inches forward of the SPP thermal radiator rotational joint Y–Z interface plane. This interface plane is defined as the attach surface of the Torque Box assembly (shown above) to the SPP core (not shown).
ORIENTATION:	X_{SPPR} The X–axis is coincident with the joint axis of rotation. The positive X–axis is away from the radiator.
	Y_{SPPR} The Y–axis is normal to the nominal plane of the deployed radiator plane. The Y–axis is in the starboard/rearward direction when the rotation angle is equal to zero.
	Z_{SPPR} The positive Z–axis completes the right–handed Cartesian system.
SUBSCRIPT:	SPPR

FIGURE 5.0–20 SCIENCE POWER PLATFORM RADIATOR COORDINATE SYSTEM

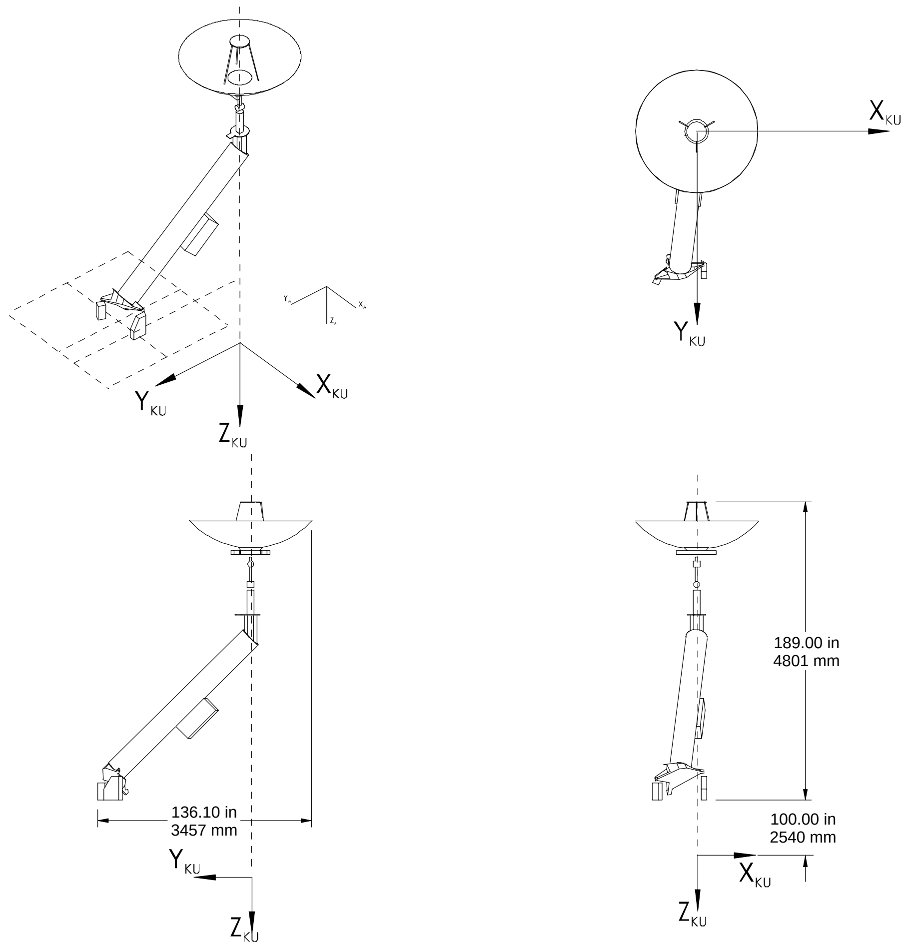


NAME:	SPP Solar Arrays
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located along the beta gimbal axis of rotation in the center of the mounting interface between the beta gimbal and the canister platform.
ORIENTATION:	Z_{SPPA} The Z–axis is perpendicular to the nominal plane of the array and is positive toward the sun.
	Y_{SPPA} The Y–axis completes the right–handed Cartesian system.
	X_{SPPA} The X–axis is coincident with the beta joint axis.
SUBSCRIPT:	SPPA

FIGURE 5.0–21 SCIENCE POWER PLATFORM ARRAYS COORDINATE SYSTEM

6.0 VIEWING REFERENCE FRAMES

The coordinate systems outlined in this chapter represent all the viewing subelements.



NAME: Tracking And Data Relay Satellite System (Ku–Band) Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed

ORIGIN: The origin is located along the Z–axis at a point 100 inches below the interface between the antenna boom and the ITS to which it attaches. The interface plane is defined as the base of the Ku–Band Antenna Boom as shown above.

ORIENTATION: Z_{KU} The Z–axis is coincident with the longitudinal plane of symmetry for the antenna boom. The positive Z–axis is away from the base of the antenna boom.

Y_{KU} The positive Y–axis is parallel to the lower antenna gimbal of rotation and in the direction of starboard when located on the Space Station in the LVLH flight orientation.

X_{KU} The positive X–axis is parallel to the upper antenna gimbal axis of rotation and in the direction of flight when located on the Space Station in the LVLH flight orientation.

SUBSCRIPT: KU

FIGURE 6.0–1 TRACKING AND DATA RELAY SATELLITE SYSTEM (KU–BAND) COORDINATE SYSTEM

TBD

NAME:	Attached Payload Ram Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
DESCRIPTION:	The Attached Payload will be attached to the Space Station so that the coordinate axes are nominally parallel to and the same sense as the Space Station Analysis Coordinate Frame axes X_A, Y_A, and Z_A.
ORIGIN:	The origin is located along the plane of symmetry at a point 100 inches inward (toward the ITS) from the interface plane with the Space Station. This interface plane is defined as the outermost face of the attach structure used to attach the payload to the ITA.
ORIENTATION:	X_{APR} The X–axis is parallel to the Space Station X_A–axis and positive in the direction of flight when attached to the Space Station.
	Y_{APR} The Y–axis is parallel to the Space Station Y_A–axis and positive toward starboard when attached to the Space Station.
	Z_{APR} The Z–axis is parallel to the Space Station Z_A–axis and positive toward nadir when attached to the Space Station.
SUBSCRIPT:	APR

FIGURE 6.0–2 ATTACHED PAYLOAD RAM COORDINATE SYSTEM

TBD

NAME:	Attached Payload Wake Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
DESCRIPTION:	The Attached Payload will be attached to the Space Station so that the coordinate axes are nominally parallel to and the same sense as the Space Station Analysis Coordinate Frame axes X_A, Y_A, and Z_A.
ORIGIN:	The origin is located along the plane of symmetry at a point 100 inches inward (toward the ITS) from the interface plane with the Space Station. This interface plane is defined as the outermost face of the attach structure used to attach the payload to the ITA.
ORIENTATION:	X_{APW} The X–axis is parallel to the Space Station X_A–axis and positive in the direction of flight when attached to the Space Station.
	Y_{APW} The Y–axis is parallel to the Space Station Y_A–axis and positive toward starboard when attached to the Space Station.
	Z_{APW} The Z–axis is parallel to the Space Station Z_A–axis and positive toward nadir when attached to the Space Station.
SUBSCRIPT:	APW

FIGURE 6.0–3 ATTACHED PAYLOAD WAKE COORDINATE SYSTEM

TBD

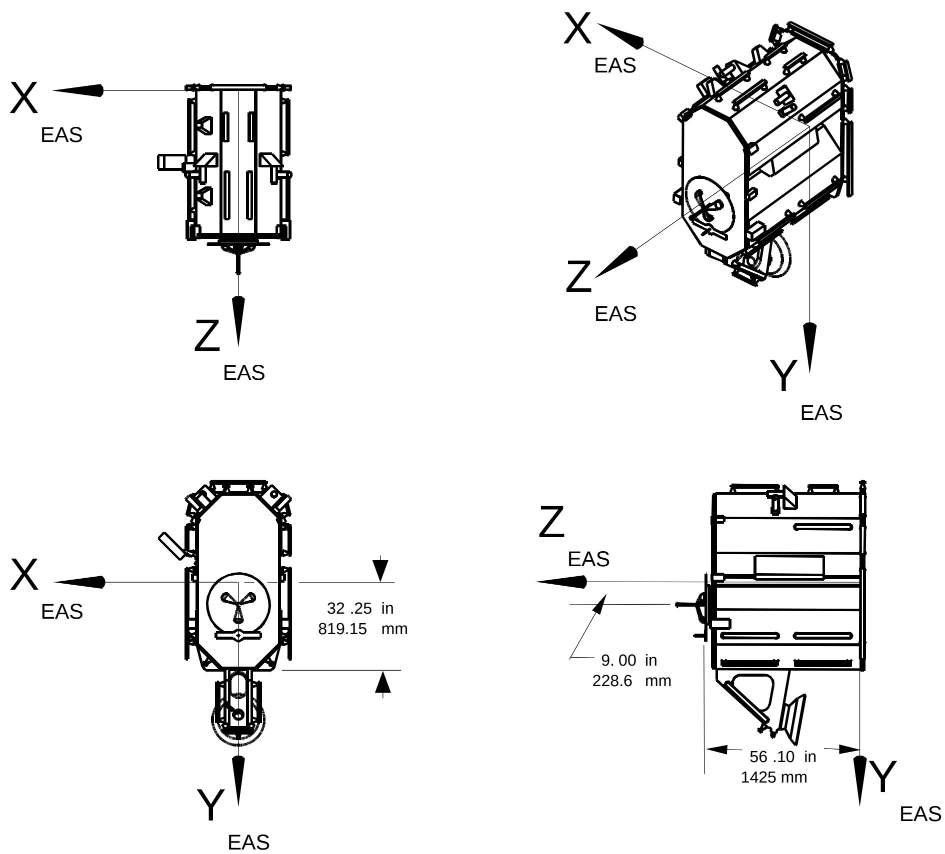
NAME:	Attached Payload Zenith Coordinate System
TYPE:	Rotating Right–Handed Cartesian, Body–Fixed
DESCRIPTION:	The Attached Payload will be attached to the Space Station so that the coordinate axes are nominally parallel to and the same sense as the Space Station Analysis Coordinate Frame axes X_A, Y_A, and Z_A.
ORIGIN:	The origin is located along the plane of symmetry at a point 100 inches inward (toward the ITS) from the interface plane with the Space Station. This interface plane is defined as the outermost face of the attach structure used to attach the payload to the ITA.
ORIENTATION:	X_{APZ} The X–axis is parallel to the Space Station X_A–axis and positive in the direction of flight when attached to the Space Station.
	Y_{APZ} The Y–axis is parallel to the Space Station Y_A–axis and positive toward starboard when attached to the Space Station.
	Z_{APZ} The Z–axis is parallel to the Space Station Z_A–axis and positive toward nadir when attached to the Space Station.
SUBSCRIPT:	APZ

FIGURE 6.0–4 ATTACHED PAYLOAD ZENITH COORDINATE SYSTEM

TBD

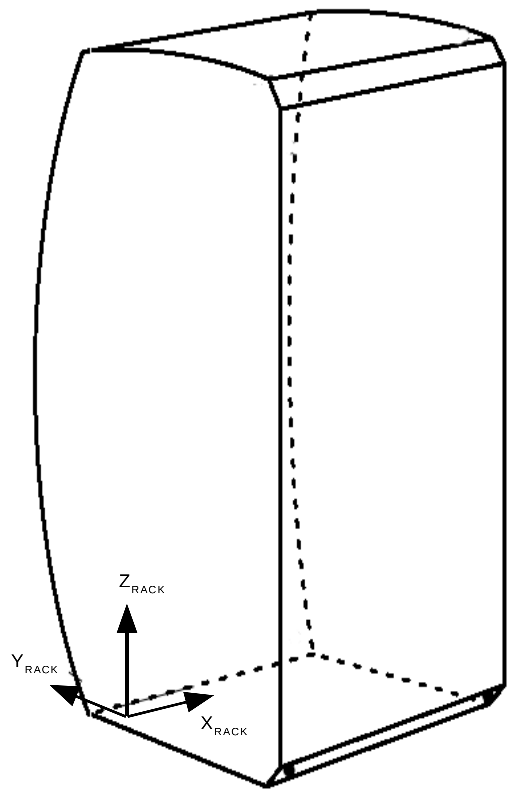
NAME:	Attached Payload Nadir Coordinate System
TYPE:	Rotating Right–Handed Cartesian, Body–Fixed
DESCRIPTION:	The Attached Payload will be attached to the Space Station so that the coordinate axes are nominally parallel to and the same sense as the Space Station Analysis Coordinate Frame axes X_A, Y_A, and Z_A.
ORIGIN:	The origin is located along the plane of symmetry at a point 100 inches inward (toward the ITS) from the interface plane with the Space Station. This interface plane is defined as the outermost face of the attach structure used to attach the payload to the ITA.
ORIENTATION:	X_{APN} The X–axis is parallel to the Space Station X_A–axis and positive in the direction of flight when attached to the Space Station.
	Y_{APN} The Y–axis is parallel to the Space Station Y_A–axis and positive toward starboard when attached to the Space Station.
	Z_{APN} The Z–axis is parallel to the Space Station Z_A–axis and positive toward nadir when attached to the Space Station.
SUBSCRIPT:	APN

FIGURE 6.0–5 ATTACHED PAYLOAD NADIR COORDINATE SYSTEM



NAME:	Early Ammonia Servicer Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located along the longitudinal center line of the interior surface of the base plate, 32.25 inches from the edge of the base plate with the P6 trunnion attachment fixture. Reference Drawing RH000191 Base Plate Assembly.
ORIENTATION:	X_{EAS} The X–axis completes the right–handed Cartesian system.
	Y_{EAS} The Y–axis is parallel to the longitudinal center line of the base plate and positive toward the P6 trunnion attachment fixture.
	Z_{EAS} The Z–axis is perpendicular to the EAS base plate positive in the direction of the grapple fixture.
SUBSCRIPT:	EAS

FIGURE 6.0–6 EARLY AMMONIA SERVICER COORDINATE STSTEM



NAME: Rack Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed

ORIGIN: The origin is located at the interface of the center line bushing attachment to the rear side of the rack.

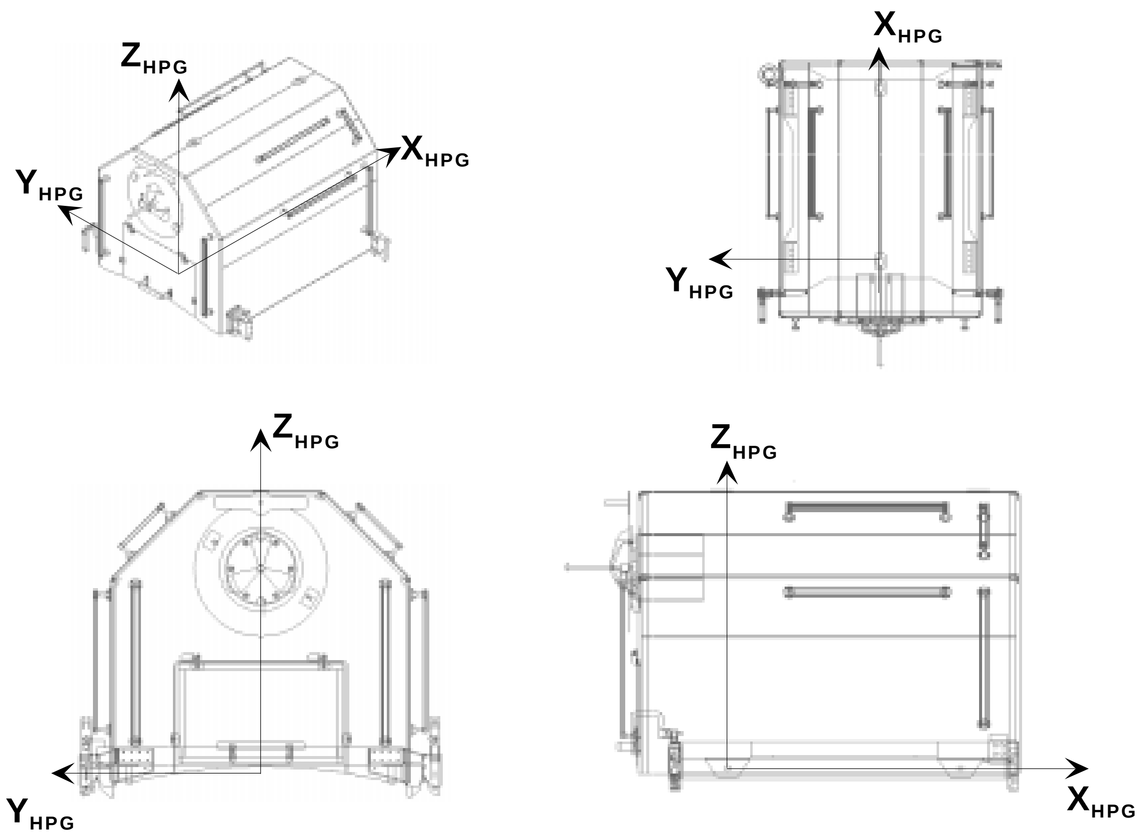
ORIENTATION: X_{RACK} The X–axis is parallel to a line through the center line bushing attachments, perpendicular to the side wall.

Y_{RACK} The Y–axis is perpendicular to the X–axis, parallel to the plane of the rack floor, and is positive to the aft of the rack rear side.

Z_{RACK} The Z–axis completes the right–handed Cartesian system.

SUBSCRIPT: RACK

FIGURE 6.0–7 RACK COORDINATE SYSTEM



NAME: O2 / N2 High Pressure Gas Tank (HPG) ORU Coordinate System

TYPE: Right–Handed Cartesian, Body Fixed

ORIGIN: The origin of the coordinate system is located at the center of a line connecting the centers of the two forward HPG ORU mechanism installation latches.

ORIENTATION: X_{HPG} The X–axis runs parallel to the HPG ORU longitudinal axis, and is shown in the positive direction.

Y_{HPG} The Y–axis lies along the line connecting the centers of the two forward HPG ORU mechanism installation latches, and is shown in the positive direction.

Z_{HPG} The Z–axis is perpendicular to the plane formed by the X_{HPG} and Y_{HPG} axes and is shown in the positive direction.

SUBSCRIPT: HPG

FIGURE 6.0–8 O2/N2 HIGH PRESSURE GAS TANK COORDINATE SYSTEM

TBD

NAME:	Solar Array ORU Coordinate System	
TYPE:	Rotating Right–Handed Cartesian, Body–Fixed	
ORIGIN:	TBD	
ORIENTATION:	X_{SAO}	TBD
	Y_{SAO}	TBD
	Z_{SAO}	TBD
SUBSCRIPT:	SAO	

FIGURE 6.0–9 SOLAR ARRAY ORU COORDINATE SYSTEM

TBD

NAME: Pump Module Assembly ORU Coordinate System

TYPE: Rotating Right–Handed Cartesian, Body–Fixed

ORIGIN: TBD

ORIENTATION: X_{PMAO} TBD

Y_{PMAO} TBD

Z_{PMAO} TBD

SUBSCRIPT: PMAO

FIGURE 6.0–10 PUMP MODULE ASSEMBLY ORU COORDINATE SYSTEM

TBD

NAME:	S1 Grapple Bar ORU Coordinate System	
TYPE:	Rotating Right–Handed Cartesian, Body–Fixed	
ORIGIN:	TBD	
ORIENTATION:	X_{S1-GBO}	TBD
	Y_{S1-GBO}	TBD
	Z_{S1-GBO}	TBD
SUBSCRIPT:	S1–GBO	

FIGURE 6.0–11 S1 GRAPPLE BAR ORU COORDINATE SYSTEM

TBD

NAME:	Radiator ORU Coordinate System
TYPE:	Rotating Right–Handed Cartesian, Body–Fixed
ORIGIN:	TBD
ORIENTATION:	X_{RORU} TBD
	Y_{RORU} TBD
	Z_{RORU} TBD
SUBSCRIPT:	RORU

FIGURE 6.0–12 RADIATOR ORU COORDINATE SYSTEM

TBD

NAME: Thermal Radiator Rotary Joint (TRRJ) ORU Coordinate System

TYPE: Rotating Right–Handed Cartesian, Body–Fixed

ORIGIN: TBD

ORIENTATION: X_{TRRJO} TBD

Y_{TRRJO} TBD

Z_{TRRJO} TBD

SUBSCRIPT: TRRJO

FIGURE 6.0–13 THERMAL RADIATOR ROTARY JOINT ORU COORDINATE SYSTEM

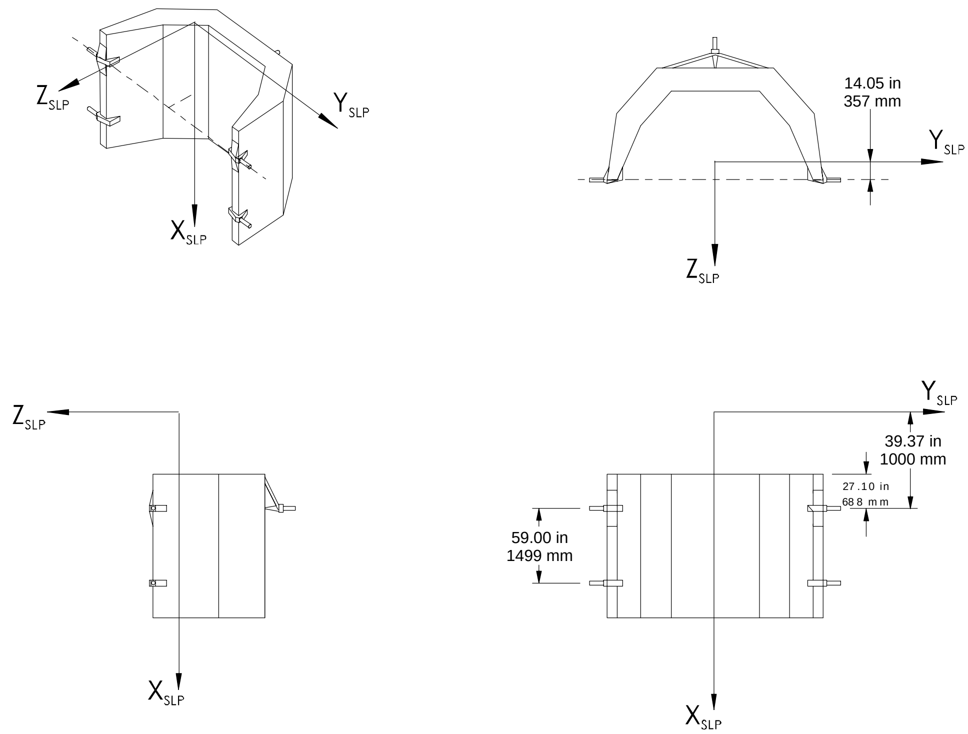
TBD

NAME:	Mast Canister ORU Coordinate System
TYPE:	Rotating Right–Handed Cartesian, Body–Fixed
ORIGIN:	TBD
ORIENTATION:	X_{MCO} TBD
	Y_{MCO} TBD
	Z_{MCO} TBD
SUBSCRIPT:	MCO

FIGURE 6.0–14 MAST CANISTER ORU COORDINATE SYSTEM

7.0 UNPRESSURIZED LOGISTICS REFERENCE FRAMES

The coordinate systems outlined in this chapter represent all the unpressurized logistics subelements.

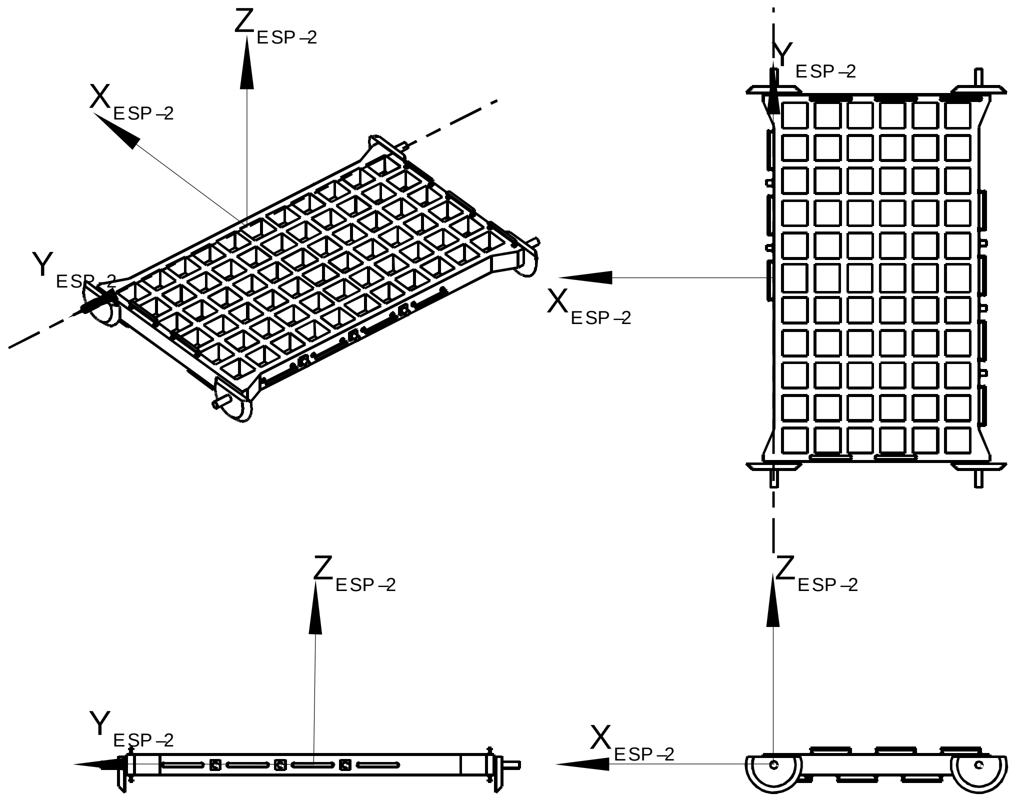


NAME:	Spacelab Pallet Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located rearward of the unpressurized module such that the center of the bases of the aft trunnions have X_{SLP} components nominally equal to 39.37 inches.
ORIENTATION:	X_{SLP} The X–axis is parallel to the plane defined by the four trunnion pin centerlines. The positive X–axis is toward the SLP.
	Z_{SLP} The Z–axis is perpendicular to the trunnion pin centerlines and parallel to the keel pin centerline. The positive Z–axis is away from the keel pin.
	Y_{SLP} The Y–axis completes the right–handed Cartesian System.
SUBSCRIPT:	SLP

FIGURE 7.0–1 SPACELAB PALLET COORDINATE SYSTEM

TBD

FIGURE 7.0–2 EDO COORDINATE SYSTEM

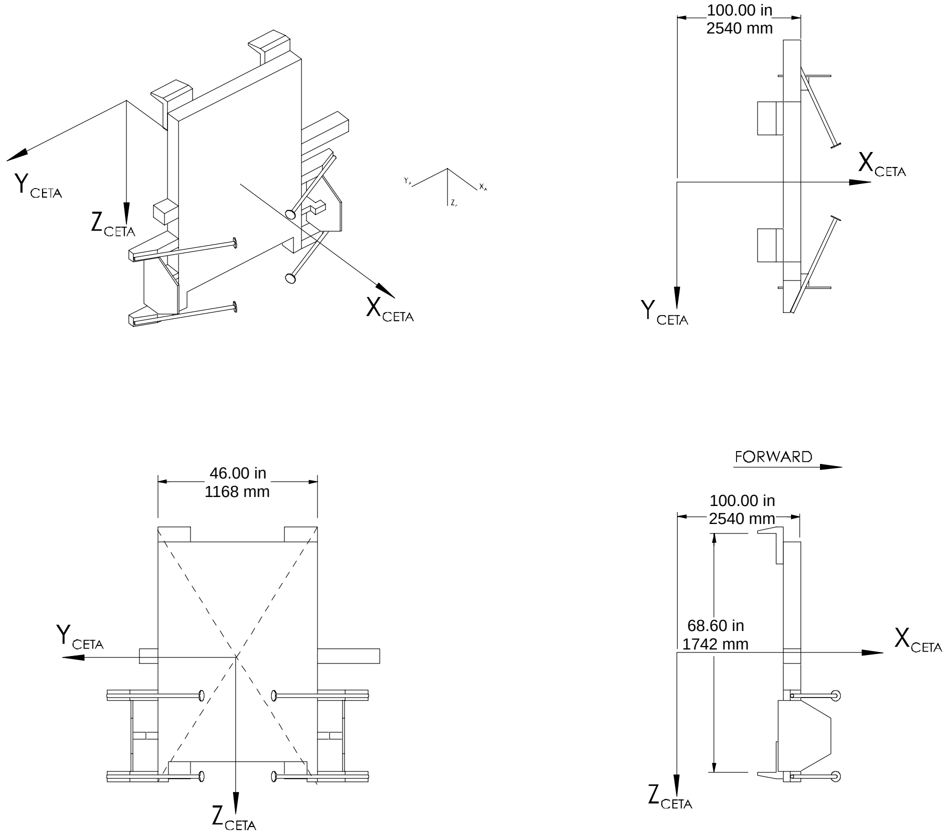


NAME:	External Stowage Platform – 2
TYPE:	Right–Handed Cartesian, Body–Fixed
ORIGIN:	The origin is located at the intersection of the primary UCP longeron trunnions and the perpendicular UCP center–plane.
ORIENTATION:	X_{SLP} The positive X axis is defined as the direction from the stabilizing to primary trunnions.
	Y_{SLP} The Y–axis follows the centerline created through the primary longeron trunnions, with the positive direction defined by the right–hand rule
	Z_{SLP} The Z–axis is perpendicular to the top plane of the ESP2 with the positive direction intersecting the top plane.
SUBSCRIPT:	ESP–2

FIGURE 7.0–3 EXTERNAL STOWAGE PLATFORM – 2

8.0 TRANSLATING REFERENCE FRAMES

The coordinate systems outlined in this chapter represent all the translating subelements. This includes the Mobile Transporter as well as the individual subelements from which the Mobile Servicing Center (MSC) is comprised. All dimensions are in inches unless otherwise noted. All drawings include an isometric view, top view, front view and side view moving left to right, top to bottom.



NAME: Crew and Equipment Translational Aid Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed

ORIGIN: The origin is located at a point 100 inches along X from the base plate forward face.

ORIENTATION: X_{CETA} The X–axis is perpendicular to the geometric plane of symmetry of the four attach points to the ITS, and is located horizontally in the geometric center of the baseplate. The positive X–axis is toward forward as shown.

Y_{CETA} The Y–axis is perpendicular to the longitudinal axis of the CETA base plate, as shown.

Z_{CETA} The Z–axis completes the right–handed Cartesian system.

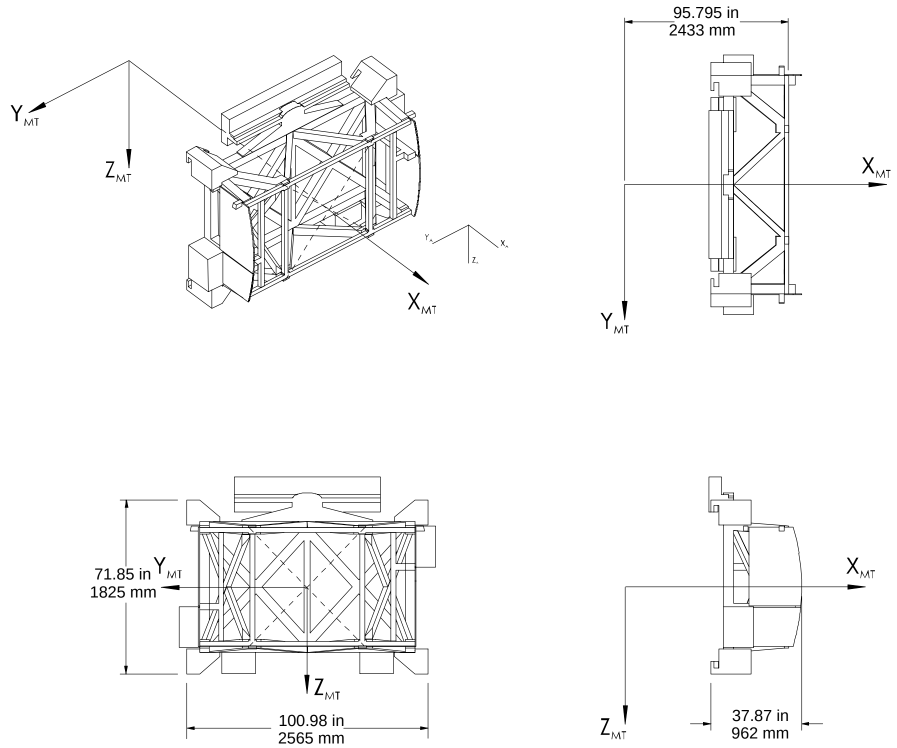
SUBSCRIPT: CETA

FIGURE 8.0–1 CREW AND EQUIPMENT TRANSLATIONAL AID COORDINATE SYSTEM

TBD

NAME:	Mobile Servicing Centre Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed
DESCRIPTION:	The Mobile Servicing Centre (MSC) is part of the MSS and consists of the MT, the MRS Base System (MBS), and the Space Station Remote Manipulator System (SSRMS) .
ORIGIN:	The origin is located on a line running through the geometric center of the MT, perpendicular to the interface plane between the MT and the MBS, at a point 100 inches from the interface plane. The interface plane is defined as the outer face of the MT structure to which the MBS attaches.
ORIENTATION:	X_{MSC} The X–axis is perpendicular to the interface plane between the MT and the MBS. The positive X–axis is toward the MSC.
	Y_{MSC} The Y–axis is parallel to and positive in the same direction as the Space Station Y–axis when the MSC is in the nominal orientation.
	Z_{MSC} The Z–axis completes the right–handed Cartesian system.
SUBSCRIPT:	MSC

FIGURE 8.0–2 MOBILE SERVICING CENTRE COORDINATE SYSTEM



NAME: Mobile Transporter Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed

DESCRIPTION: The MT is part of the MSC.

ORIGIN: The origin is located on a line running through the geometric center of the MT, perpendicular to the interface plane between the MT and the MBS, at a point 95.79 inches from the interface plane. The geometric center of the MT is located along a line equidistant from the four MT to MBS cup and cone centerlines as shown in SSP 42003, Part 2, Rev. A, Figure A3.2–3 “MBS to MT Mechanical Interface.” The interface plane is defined as the common datum plane for the cups and cones, respectively, by which the MT and the MBS structures are joined. This interface plane is shown in SSP 42003, Part 2, Rev A, Figure A3.2–6 “MBS to MT Mechanical Interface,” as being 29.41 inches from the datum A (the top rail surface of the Integrated Truss Segments) when the MT is in the latched condition. Thus, for the launch condition, the origin is also located on the axis of the integrated truss S0.

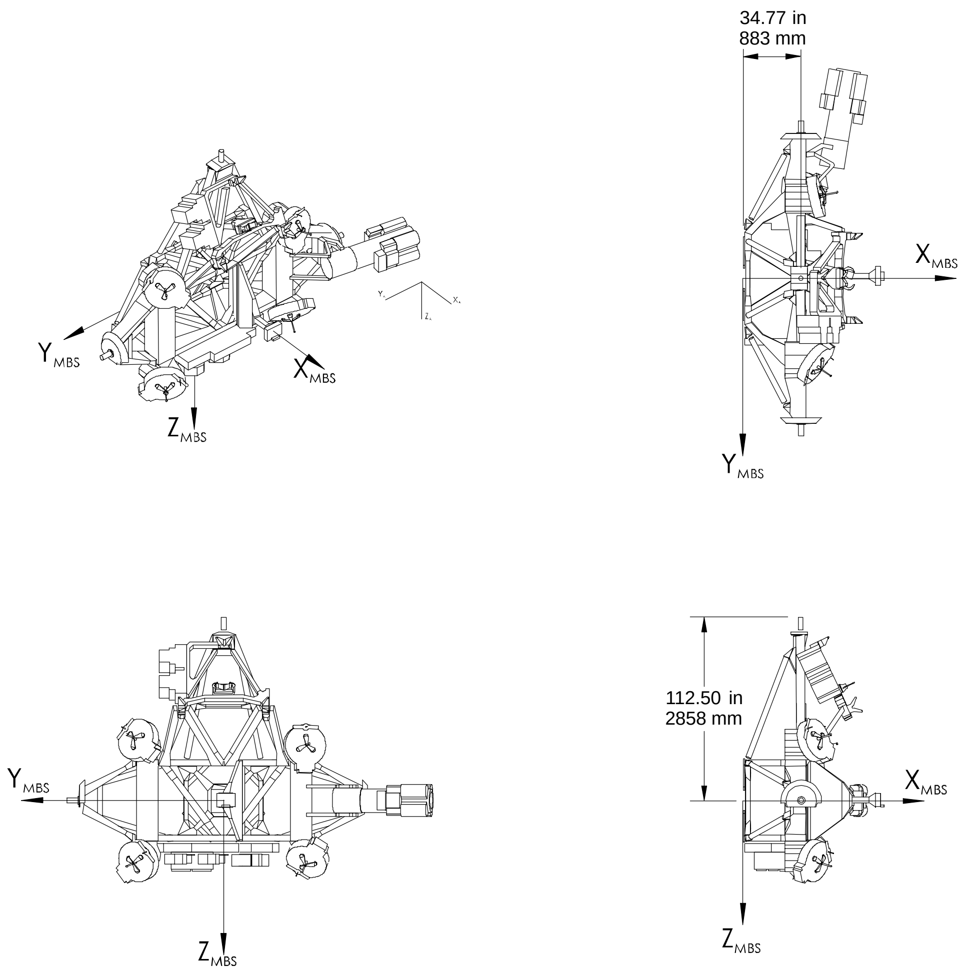
ORIENTATION: X_{MT} The X–axis is perpendicular to the interface plane between the MT and the MBS. The positive X–axis is toward the MT.

Y_{MT} The Y–axis is parallel to and positive in the same direction as the Space Station Y–axis when the MT is located on the Space Station.

Z_{MT} The Z–axis completes the right–handed Cartesian system.

SUBSCRIPT: MT

FIGURE 8.0–3 MOBILE TRANSPORTER COORDINATE SYSTEM



NAME: MSC Base System Coordinate System

TYPE: Rotating Right–Handed Cartesian, Body–Fixed

DESCRIPTION: The MBS is part of the MSC.

ORIGIN: The origin is located at the intersection of the MBS base plane and a line perpendicular to the base plane, running through the midpoint between the centers of the bases of the two trunnions. The MBS base plane is defined as the interface between the 4 MT to MBS microconical fittings and the MBS structure. This plane is 34.77 inches from the trunnion centerline.

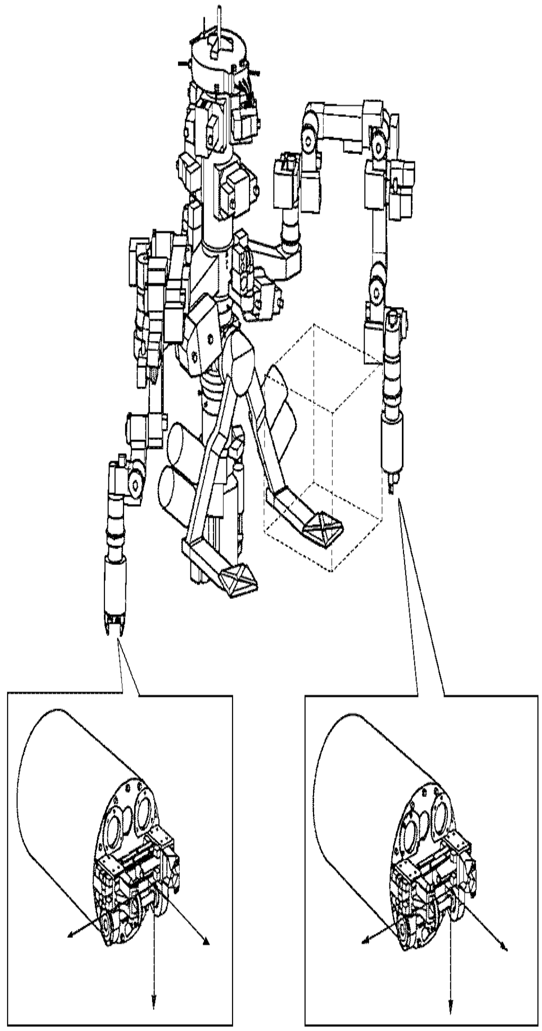
ORIENTATION: X_{MBS} The X–axis is perpendicular to the interface plane between the MT and the MBS. The positive X–axis is from the MBS base plane toward the trunnions.

Y_{MBS} The Y–axis is parallel to the projection of the line between the two trunnion base centers onto the interface plane, positive as shown.

Z_{MBS} The Z–axis completes the right–handed Cartesian system.

SUBSCRIPT: MBS

FIGURE 8.0–4 MOBILE SERVICING CENTRE BASE SYSTEM COORDINATE SYSTEM

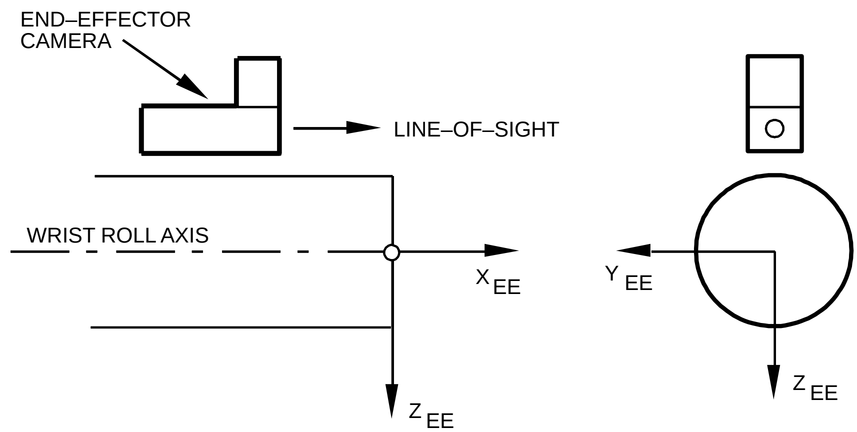


NAME:	OTCM Operating Coordinate System
TYPE:	Right–Handed Cartesian system
DESCRIPTION:	The OTCM Operating Coordinate System
ORIGIN:	The origin is located at the geometric center of the gripper jaw
ORIENTATION:	X_{OTCM} The X–axis is along the wrist roll axis of the tool change out mechanism, with positive direction along the camera line–of–sight.
	Y_{OTCM} The Y–axis is oriented as positive right as seen through the tool change–out mechanism camera.
	Z_{OTCM} The positive Z–axis completes the right–handed Cartesian system.
SUBSCRIPT:	OTCM

FIGURE 8.0–5 OTCM OPERATING COORDINATE SYSTEM

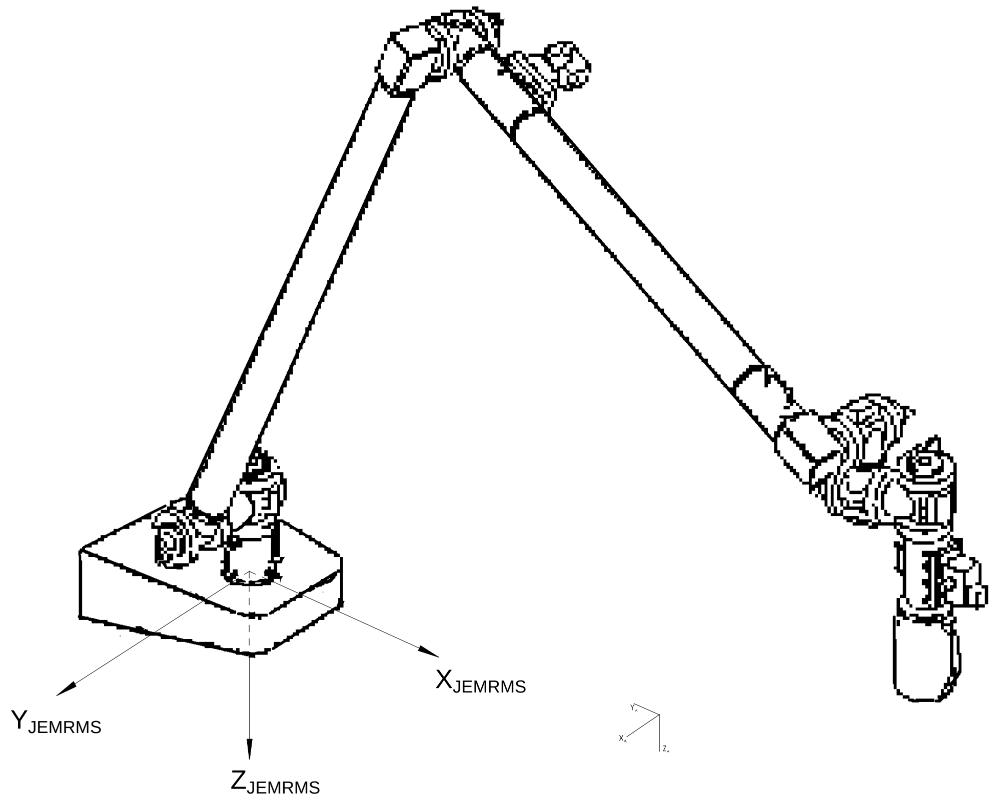
DELETED

FIGURE 8.0–6 DELETED



NAME:	End Effector Operating System
TYPE:	Right–Handed Cartesian
DESCRIPTION:	TBD
ORIGIN:	The origin is located on the wrist roll joint axis at the tip of the end effector
ORIENTATION:	X_{EE} The X_{EE} –axis is parallel with the wrist roll axis. Positive X EE is along the line of sight as seen through the end effector camera.
	Y_{EE} Y_{EE} is positive right as seen through the end effector camera.
	Z_{EE} Positive Z_{EE} is down as seen through the end effector camera
SUBSCRIPT:	EE

FIGURE 8.0–7 END EFFECTOR (EE) OPERATING COORDINATE SYSTEM



NAME: JEM – Remote Manipulator System coordinate system

TYPE: Rotating Right–Handed Cartesian, Body–Fixed to the JEMRMS Base

ORIGIN: The origin is located at the geometric center of the interface plane between the JEM PM and the JEMRMS

ORIENTATION:

X_{JEMRMS} The X–axis is parallel to and positive in the same direction as the JEM PM X–axis

Z_{JEMRMS} The Z–axis is perpindicular to the interface plane between the JEM PM and the JEMRMS and positive in the opposite direction as the JEM PM Z–axis.

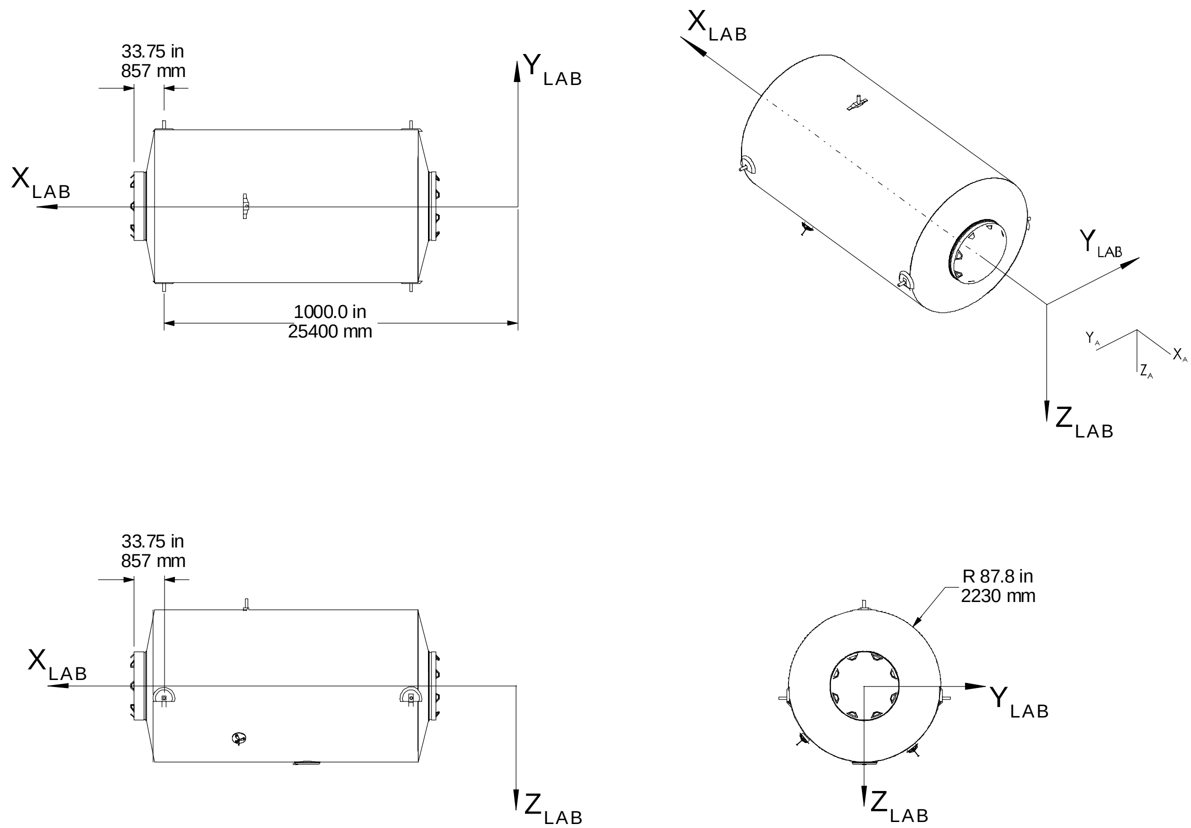
Y_{JEMRMS} The Y–axis completes the right–handed Cartesian system.

SUBSCRIPT: JEMRMS

FIGURE 8.0–8 JEM – REMOTE MANIPULATOR SYSTEM COORDINATE SYSTEM

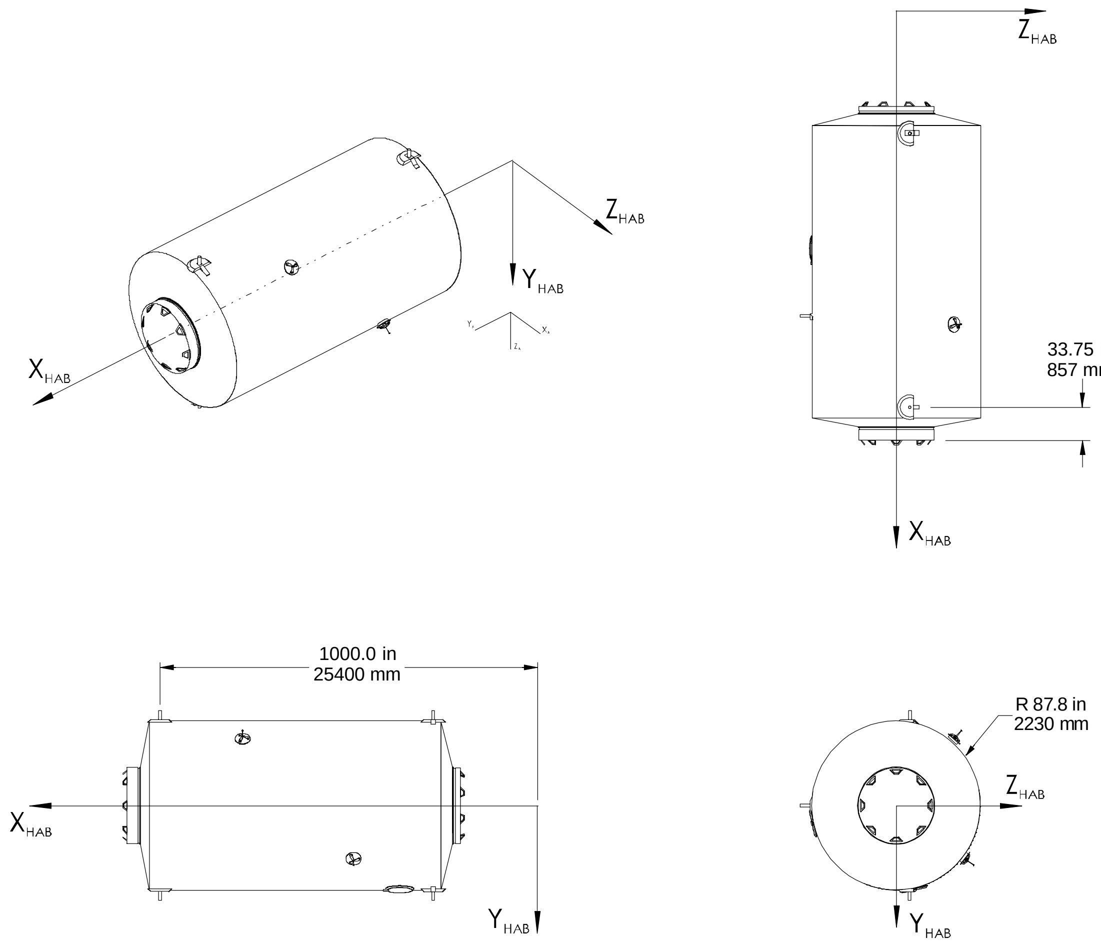
9.0 PRESSURIZED MODULE REFERENCE FRAMES

The coordinate systems outlined in this chapter represent all the pressurized module subelements. All dimensions are in inches unless otherwise specified. All drawings include an isometric view, top view, front view and side view moving left to right, top to bottom. The descriptive terms nadir, zenith, aft, forward, port, and starboard, when used, are the directions or faces of the module as nominally mated to the ISS.



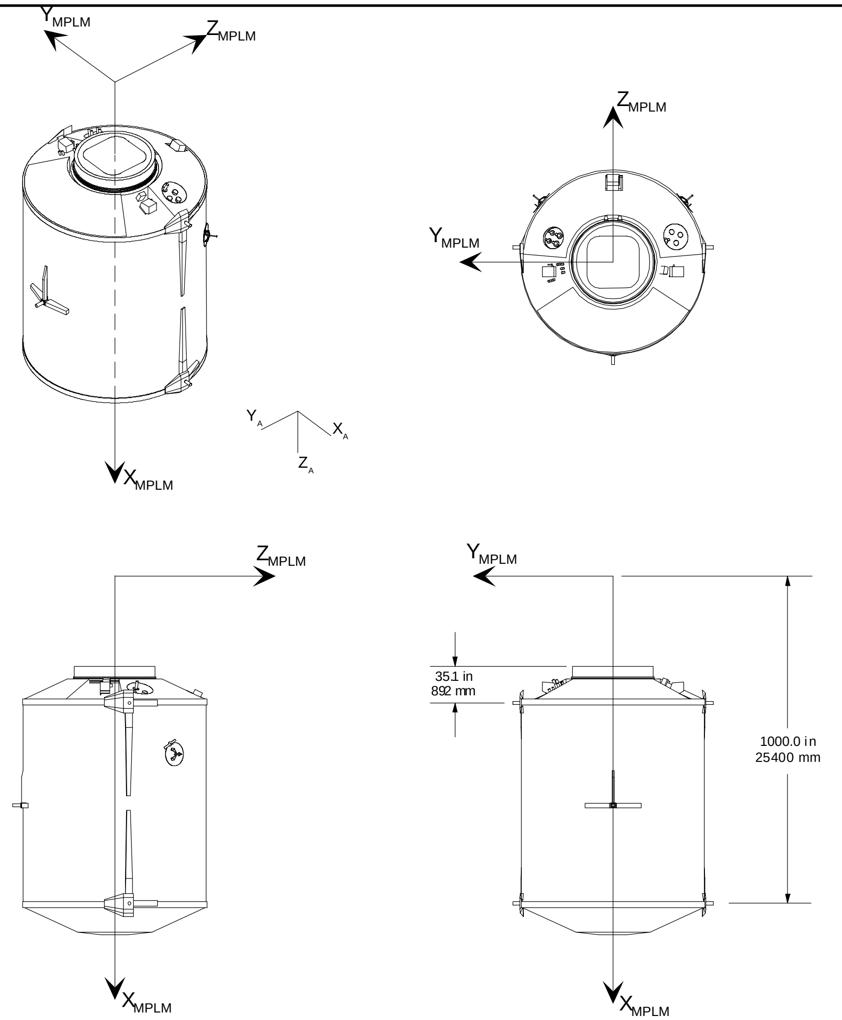
NAME:	United States Laboratory Module Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located forward of the pressurized module such that the center of the bases of the aft trunnions have X_{LAB} components nominally equal to 1000.000 inches.
ORIENTATION:	X_{LAB} The X–axis is perpendicular to the nominal aft CBM interface plane and pierces the geometric center of the array of mating bolts at the aft end of the pressurized module. The positive X–axis is toward the pressurized module from the origin.
	Z_{LAB} The Z–axis is parallel to the perpendicular line from the X–axis to the center of the base of the keel pin, and positive in the opposite direction as shown.
	Y_{LAB} The Y–axis completes the right–handed Cartesian system.
SUBSCRIPT:	LAB

FIGURE 9.0–1 UNITED STATES LABORATORY MODULE COORDINATE SYSTEM



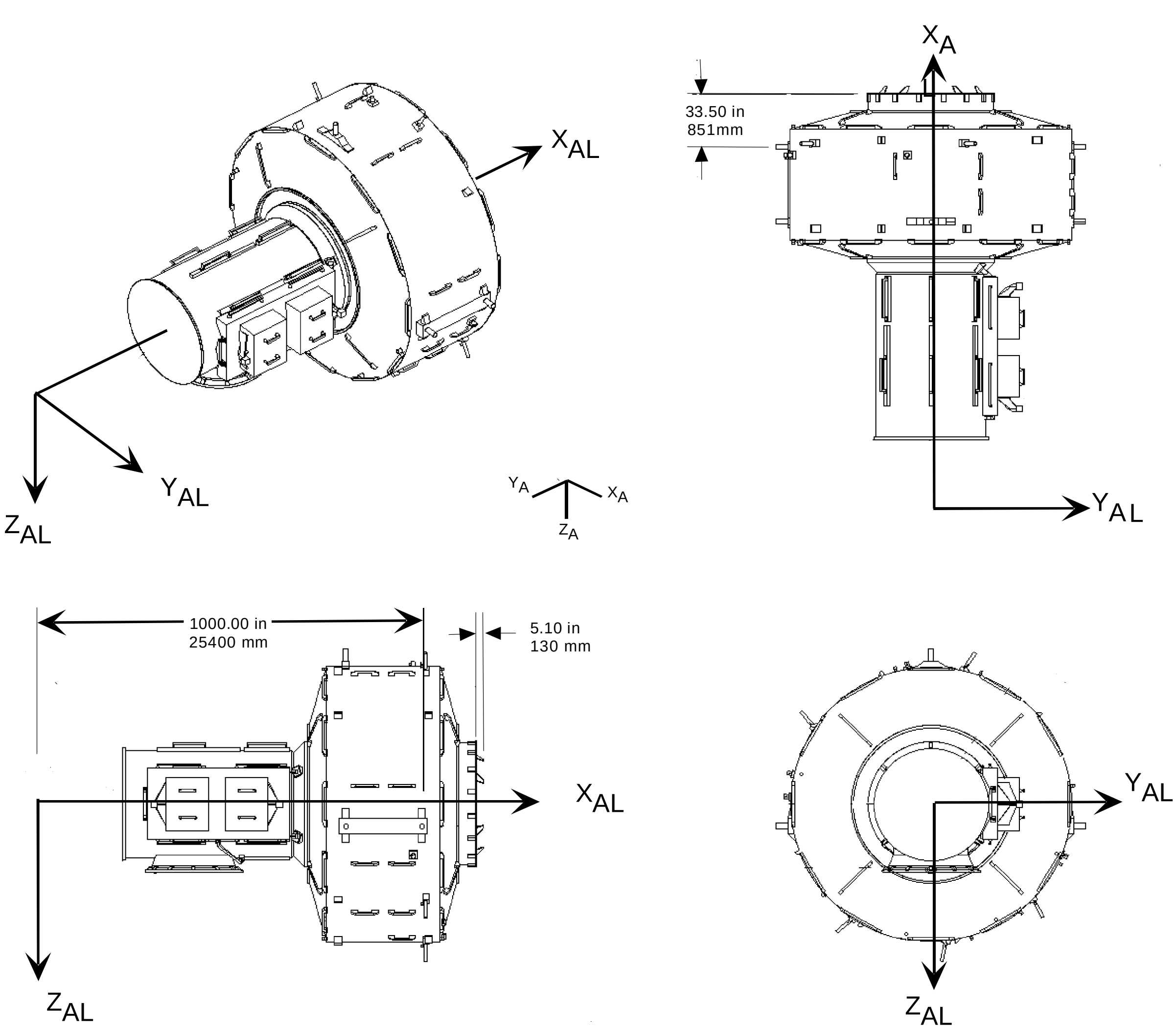
NAME:	United States Habitation Module Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located to port of the pressurized module such that the centers of the bases of the starboard trunnions have X_{HAB} components nominally equal to 1000.000 inches.
ORIENTATION:	X_{HAB} The X–axis is perpendicular to the nominal starboard CBM interface plane and pierces the geometric center of the array of mating bolts at the starboard end of the pressurized module. The positive X–axis is toward the pressurized module from the origin.
	Z_{HAB} The Z–axis is parallel to the perpendicular line from the X–axis to the center of the base of the keel pin, and positive in the opposite direction as shown.
	Y_{HAB} The Y–axis completes the right–handed Cartesian system.
SUBSCRIPT:	HAB

FIGURE 9.0–2 UNITED STATES HABITATION MODULE COORDINATE SYSTEM



NAME:	Mini Pressurized Logistics Module Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located to zenith of the pressurized module such that the centers of the bases of the nadir trunnions have X_{MPLM} components nominally equal to 1000.00 inches.
ORIENTATION:	X_{MPLM} The X–axis is perpendicular to the nominal zenith CBM interface plane and pierces the geometric center of the array of mating bolts at the zenith end of the pressurized module. The positive X–axis is toward the pressurized module from the origin.
	Z_{MPLM} The Z–axis is parallel to the perpendicular line from the X–axis to the center of the base of the keel pin, and positive in the opposite direction as shown.
	Y_{MPLM} The Y–axis completes the right–handed Cartesian system.
SUBSCRIPT:	MPLM

FIGURE 9.0–3 MINI PRESSURIZED LOGISTICS MODULE COORDINATE SYSTEM



NAME: Joint Airlock Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed to the Pressurized Module

ORIGIN: The origin is forward of the module such that the center of the bases of the aft trunnions have X_{AL} components equal to 1000.00 inches.

ORIENTATION: X_{AL} The X–axis is perpendicular to the nominal CBM interface plane and pierces the geometric center of the array of CBM mating bolts. The positive X–axis is toward the pressurized module from the origin.

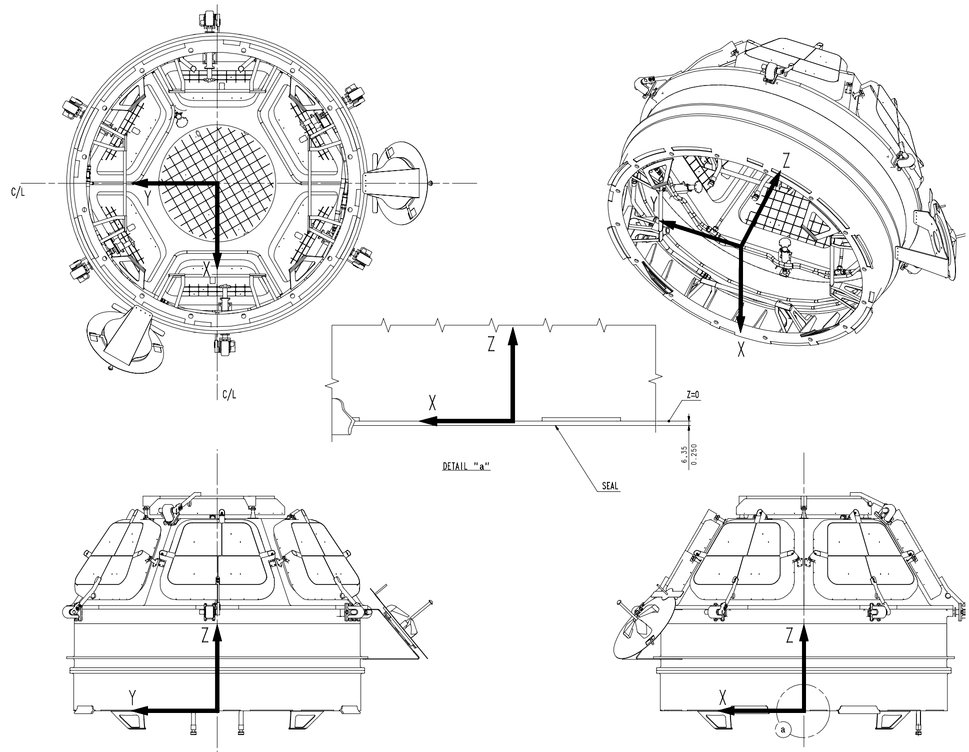
Z_{AL} The Z–axis is parallel to the perpendicular line from the X–axis to the center of the base of the keel pin, and positive in the opposite direction as shown.

Y_{AL} The Y–axis completes the right–handed Cartesian system.

SUBSCRIPT: AL

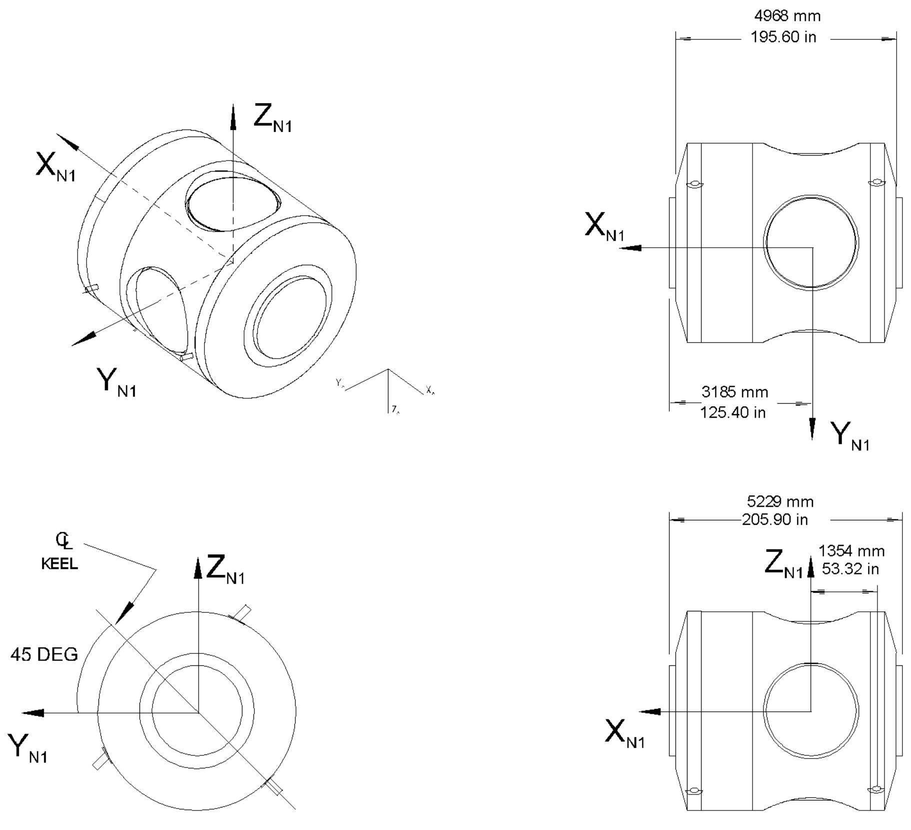
SPECIAL NOTE: For pre–Flight 7A mission planning and flight products, use the coordinate system as defined in Payload Data Package – ISS 7A, Annex 1 (NSTS 21390). For any post flight analysis or data products, use the coordinate system as defined by this figure.

FIGURE 9.0–4 JOINT AIRLOCK COORDINATE SYSTEM



NAME:	Cupola Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located on the interface plane between the Active Common Berthing Mechanism (ACBM) and the Passive Common Berthing Mechanism (PCBM) which is part of the cupola and at the geometric center of the array of CBM mating bolts.
ORIENTATION:	Z_{CUP} The Z–axis is perpendicular to the interface plane between ACBM and PCBM. The positive Z–axis passes through the center of the overhead window (Top Window).
	X_{CUP} The X–axis is on the interface plane, perpendicualr to the Z–axis and passes through the center of the window plenum and through the point midway between the centers of the Water inlet/outlet. The positive X–axis is in the opposite direction with respect to the water inlet/outlet.
	Y_{CUP} The Y–axis completes the right–handed Cartesian system.
SUBSCRIPT:	CUP

FIGURE 9.0–5 CUPOLA COORDINATE SYSTEM



NAME: Resource Node 1 Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed to the Pressurized Module

ORIGIN: The origin is located at the intersection of the lines drawn through the radial and axial port centerlines.

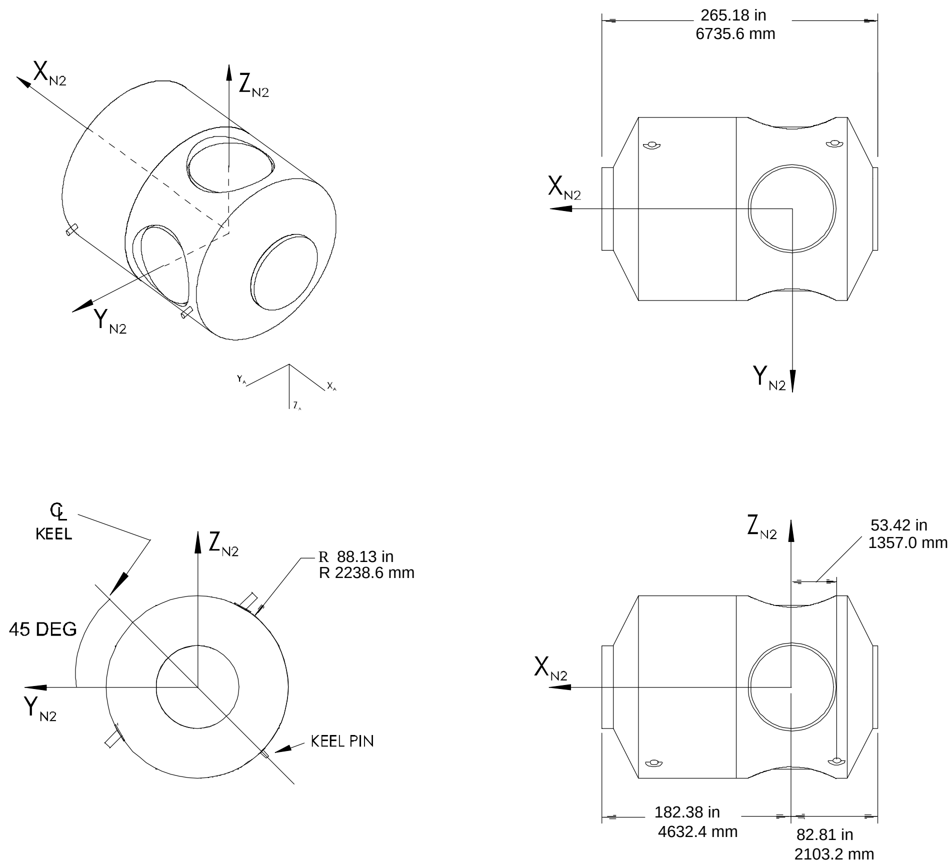
ORIENTATION: X_{N1} The X–axis is a line perpendicular to the aft CBM mating plane which pierces the geometric center of the array of aft CBM mating bolts, positive aft.

Z_{N1} The Z–axis completes the right–handed Cartesian system.

Y_{N1} The positive Y–axis is the line perpendicular to the X–axis which pierces the starboard CBM mating plane at the geometric center of the starboard CBM array of mounting bolts.

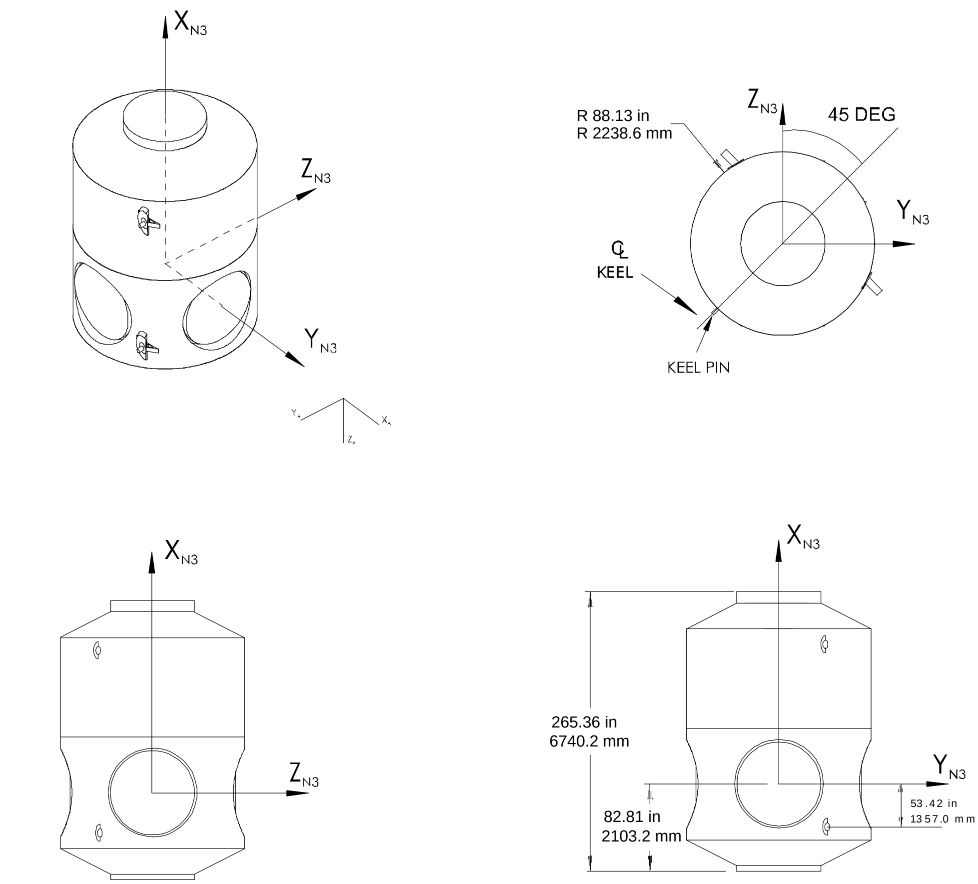
SUBSCRIPT: N1

FIGURE 9.0–6 RESOURCE NODE 1 COORDINATE SYSTEM



NAME:	Resource Node 2 Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located at the intersection of the lines drawn through the radial and axial port centerlines.
ORIENTATION:	X_{N2} The X–axis is a line perpendicular to the aft CBM mating plane which pierces the geometric center of the array of aft CBM mating bolts, positive aft.
	Z_{N2} The Z–axis completes the right–handed Cartesian system.
	Y_{N2} The positive Y–axis is the line perpendicular to the X–axis which pierces the starboard CBM mating plane at the geometric center of the starboard CBM array of mounting bolts.
SUBSCRIPT:	N2

FIGURE 9.0–7 RESOURCE NODE 2 COORDINATE SYSTEM



NAME: Resource Node 3 Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed to the Pressurized Module

ORIGIN: The origin is located at the intersection of the lines drawn through the radial and axial port centerlines.

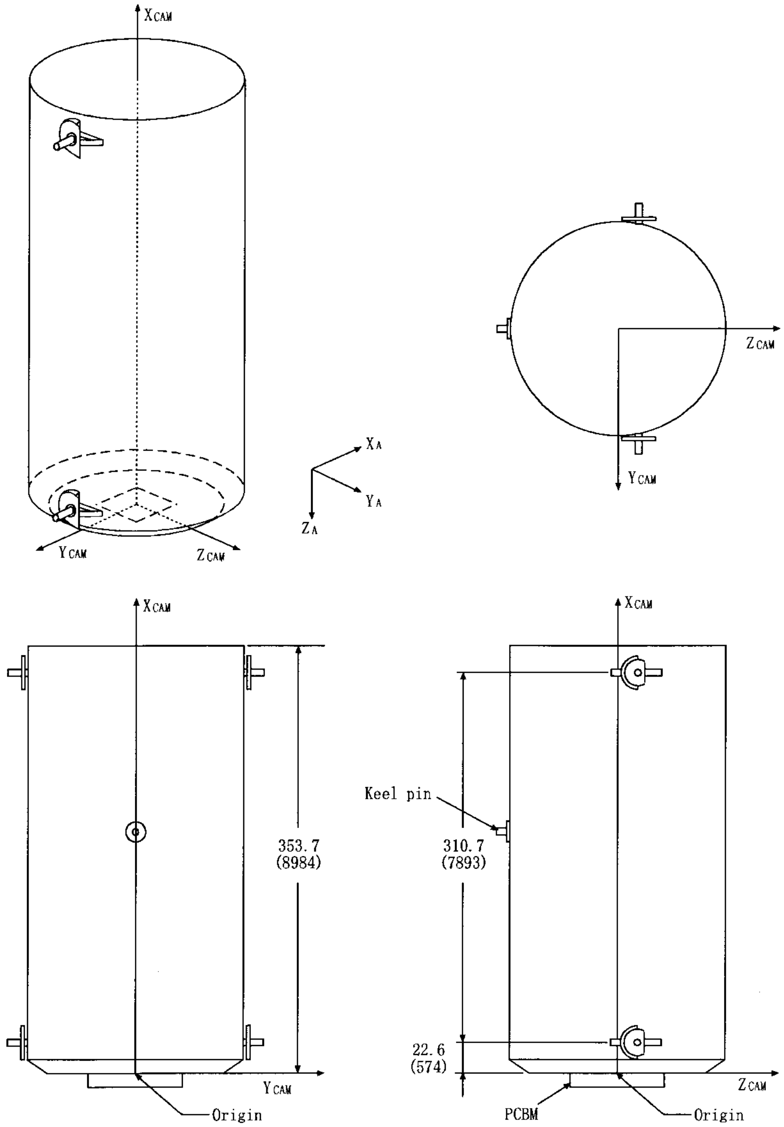
ORIENTATION: X_{N3} The X–axis is a line positive toward the axial port at the rack end of the module (the axial port furthest away from the radial ports).

Y_{N3} The positive Y–axis is a line perpendicular to the X–axis and is positive 135 degrees from the keel pin.

Z_{N3} The Z–axis completes the right–handed Cartesian system.

SUBSCRIPT: N3

FIGURE 9.0–8 RESOURCE NODE 3 COORDINATE SYSTEM



NAME: Centrifuge Accommodation Module Coordinate System

TYPE: Rotating Right–Handed Cartesian, Body–Fixed to the Pressurized Module

ORIGIN: The origin is located on the interface plane between the CAM structure and the passive common berthing mechanism (PCBM) and at the geometric center of the array of CBM mating bolts as shown.

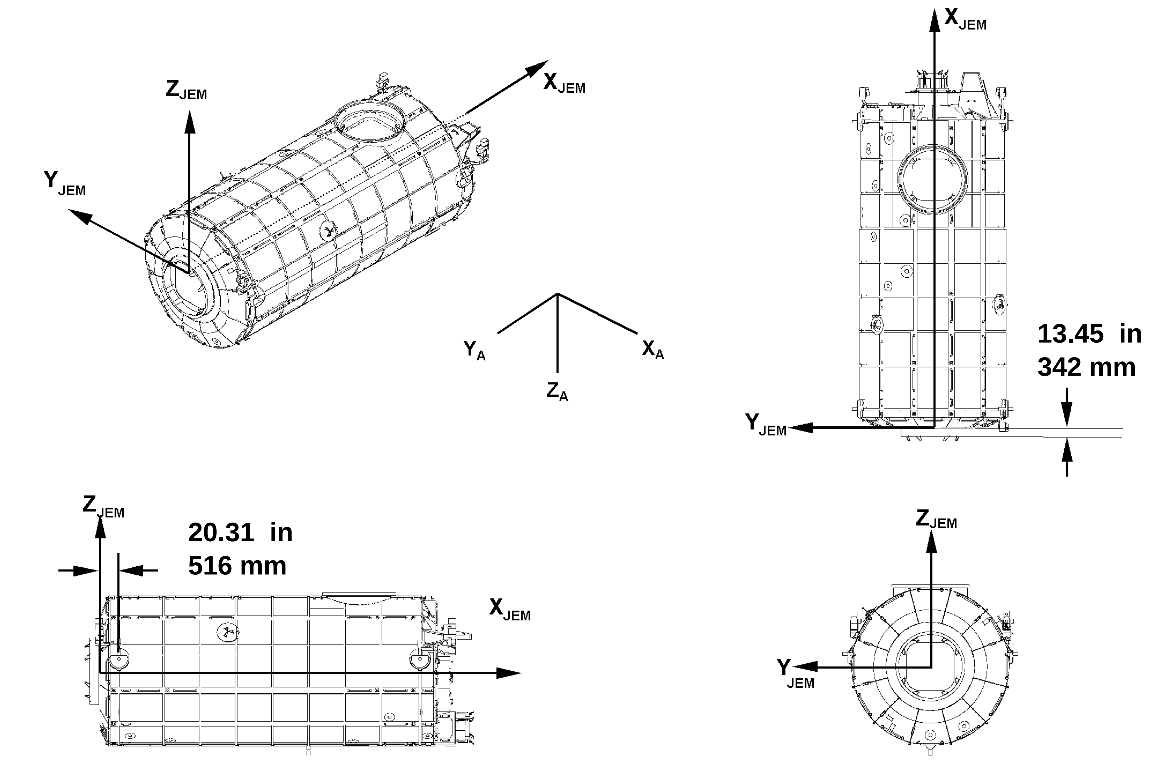
ORIENTATION: X_{CAM} The X–axis is perpendicular to the nominal CBM interface plane and pierces the geometric center of the array of CBM mating bolts. The positive X–axis is toward the pressurized module from the origin.

Z_{CAM} A vector, which points perpendicularly from the X axis to the base of the keel pin, defines the negative Z direction. The Z axis points from the origin to the opposite direction of the vector defined above.

Y_{CAM} The Y–axis completes the right–handed Cartesian system.

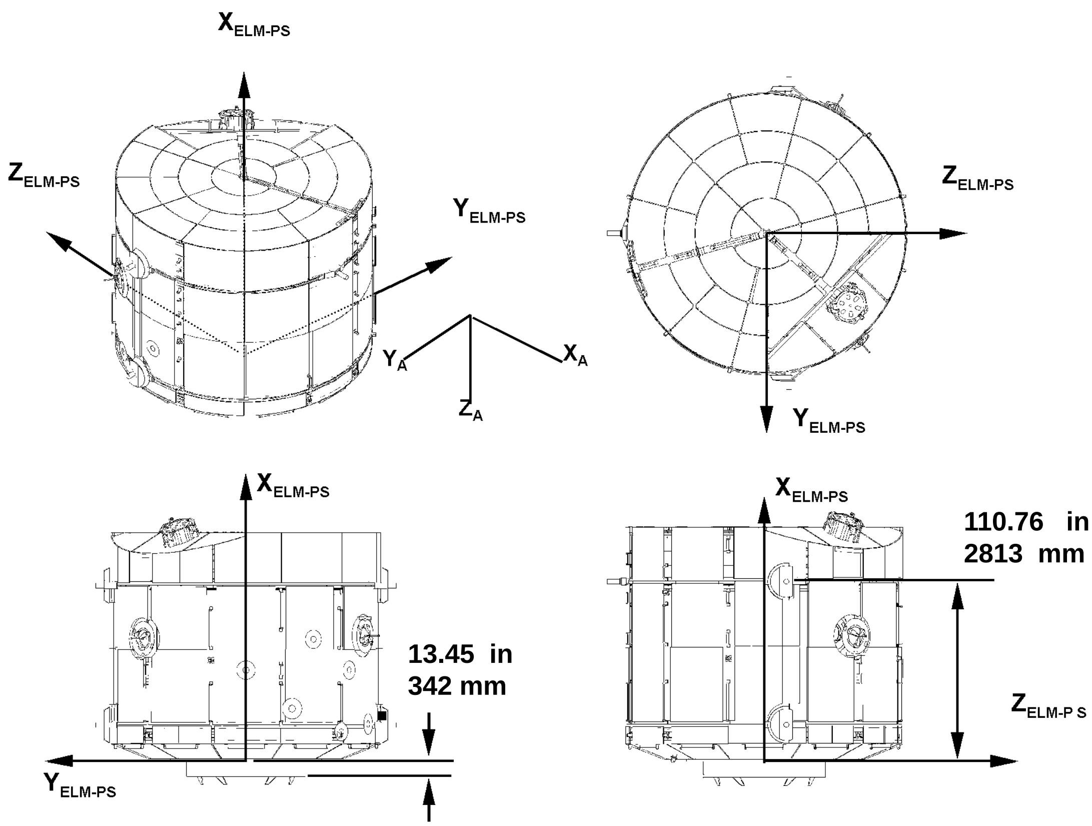
SUBSCRIPT: CAM

FIGURE 9.0–9 CENTRIFUGE ACCOMMODATION MODULE COORDINATE SYSTEM



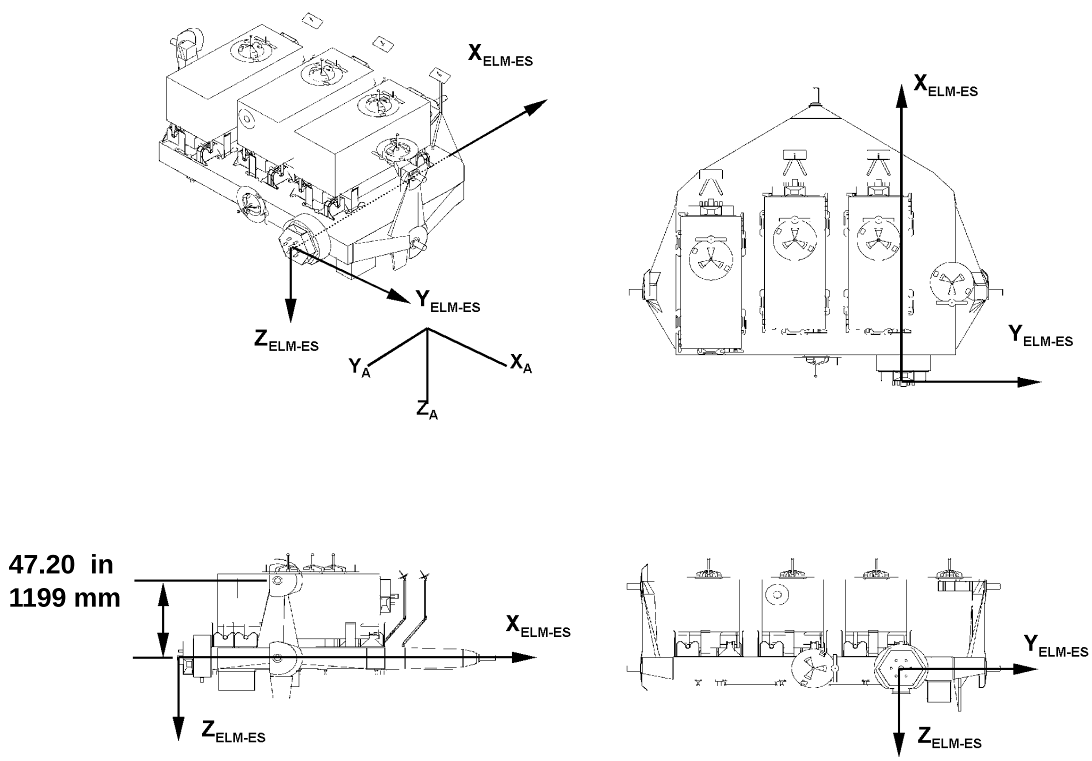
NAME:	Japanese Experiment Module (JEM) – Pressurized Module (PM) Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located on a plane 13.4 inches (341.6 mm) from the Common Berthing Mechanism (CBM) mating plane toward positive X_{JEM} through the geometric center of the array of CBM mating bolts as shown.
ORIENTATION:	X_{JEM} The X–axis is perpendicular to the nominal CBM interface plane and positive toward the opposite end of the pressurized module as shown.
	Z_{JEM} The Z–axis is parallel to the perpendicular line from the X–axis the center of the base of the keel pin, and positive in the opposite direction as shown.
	Y_{JEM} The Y–axis completes the right–handed Cartesian system.
SUBSCRIPT:	JEM

FIGURE 9.0–10 JAPANESE EXPERIMENT MODULE (JEM) — PRESSURIZED MODULE (PM) COORDINATE SYSTEM



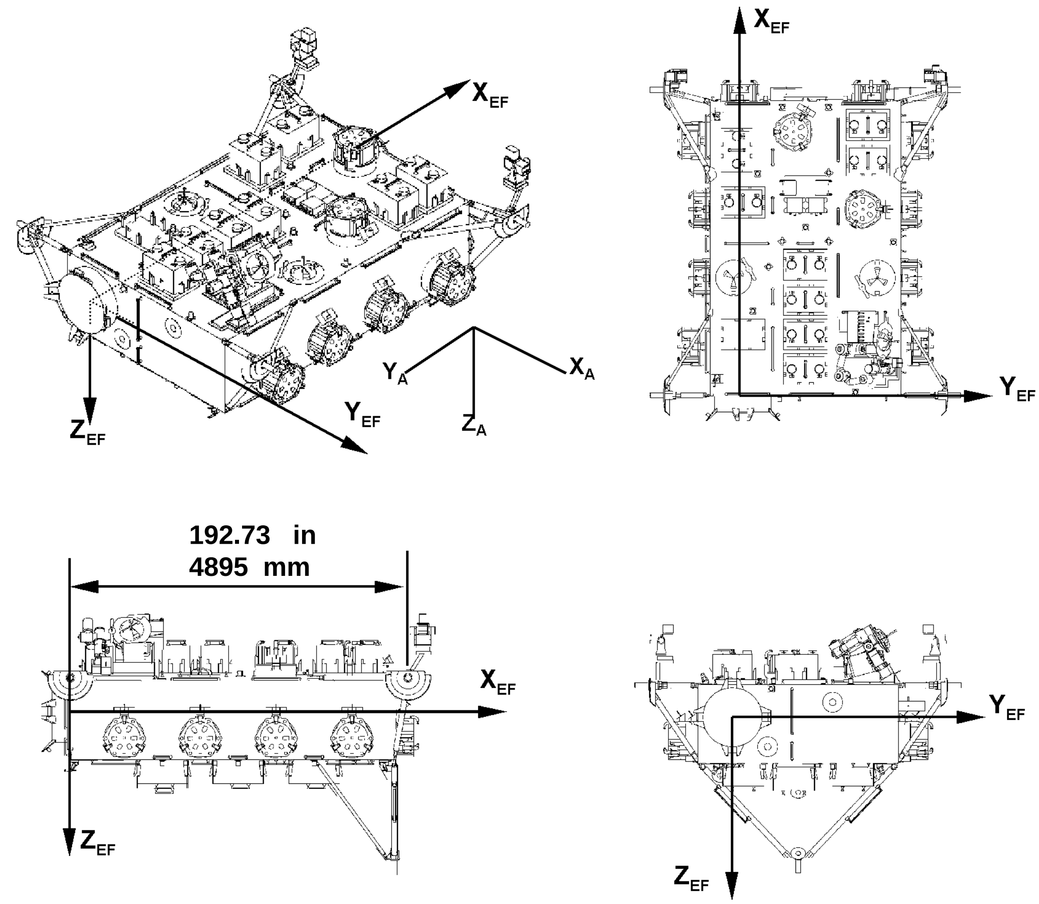
NAME:	Japanese Experiment Module Experimental Logistics Module Pressurized Section Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located on 13.4 inches (341.6 mm) from common berthing mechanism (CBM) mating plane toward positive $X_{ELM–PS}$ through the geometric center of the array of CBM mating bolts as shown.
ORIENTATION:	$X_{ELM–PS}$ The X–axis is perpendicular to the nominal CBM interface plane and positive toward the opposite end of the pressurized module as shown.
	$Z_{ELM–PS}$ The Z–axis is parallel to the perpendicular line from the X–axis to the center of the base of the keel pin, and positive in the opposite direction as shown.
	$Y_{ELM–PS}$ The Y–axis completes the right–handed Cartesian system.
SUBSCRIPT:	ELM–PS

FIGURE 9.0–11 JAPANESE EXPERIMENT MODULE EXPERIMENTAL LOGISTICS MODULE PRESSURIZED SECTION COORDINATE SYSTEM



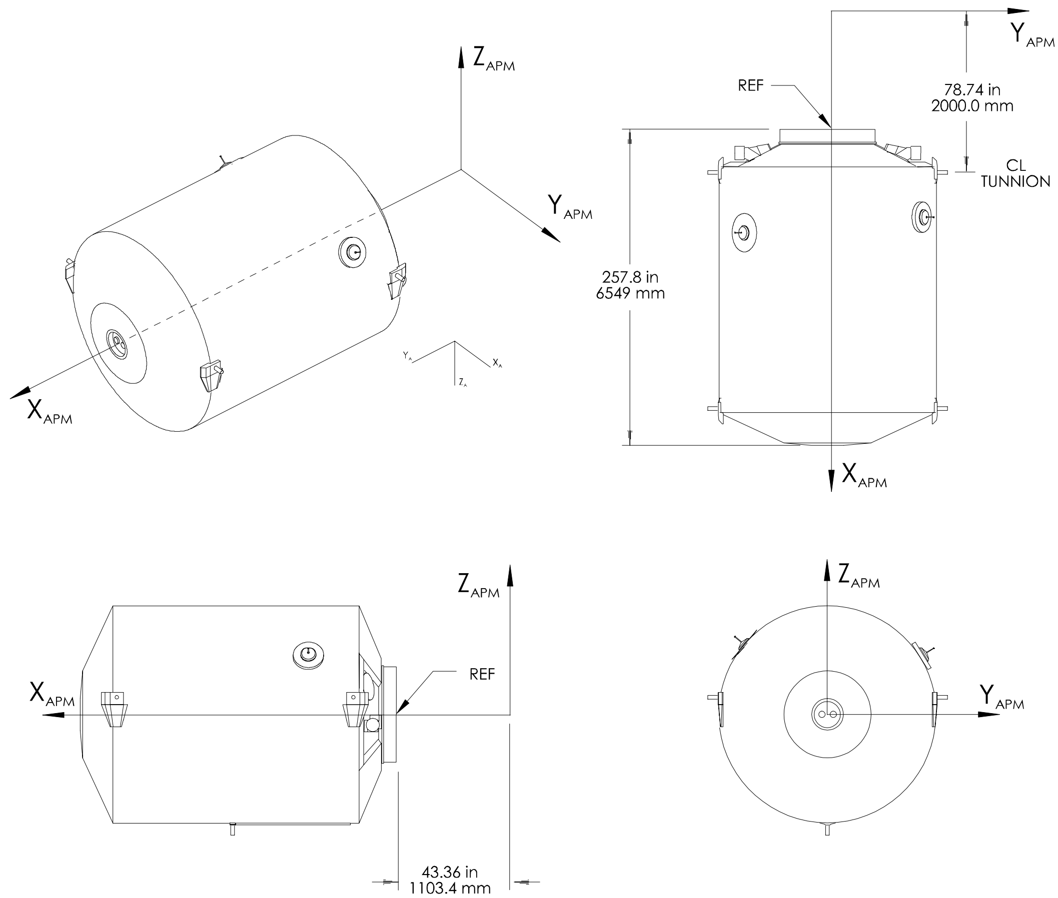
NAME:	Japanese Experiment Module – Experimental Logistics Module Exposed Section Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the ELM–ES
ORIGIN:	The origin is located at the geometric center of the interface between the JEM EF and the JEM ELM–ES.
ORIENTATION:	$X_{ELM–ES}$ The X–axis is perpendicular to the interface plane between the JEM EF and the JEM ELM–ES and positive toward the keel pin.
	$Y_{ELM–ES}$ The Y–axis is parallel to the line connecting the centers of the bases of the trunnion pins and positive forward.
	$Z_{ELM–ES}$ The Z–axis completes the right–handed Cartesian System.
SUBSCRIPT:	ELM–ES

FIGURE 9.0–12 JAPANESE EXPERIMENT MODULE — EXPERIMENTAL LOGISTICS MODULE EXPOSED SECTION COORDINATE SYSTEM



NAME:	Japanese Experiment Module Exposed Facility Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the JEM–EF
ORIGIN:	The origin is located at the geometric center of the interface between the JEM EF and the EFBM (EF Berthing Mechanism).
ORIENTATION:	X_{EF} The X–axis is perpendicular to the EF/JEM–PM interface plane and passes through the center of the interface.
	Z_{EF} The Z–axis completes the right–handed Cartesian system.
	Y_{EF} The Y–axis is parallel to the line connecting the centers of the bases of the starboard trunnion pins and is positive forward.
SUBSCRIPT:	EF

FIGURE 9.0–13 JAPANESE EXPERIMENT MODULE EXPOSED FACILITY COORDINATE SYSTEM



NAME: ESA Attached Pressurized Module Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed to the Pressurized Module

ORIGIN: The origin is located to port of the pressurized module such that the centers of the bases of the port trunnions have X_{APM} components nominally equal to 78.740 inches.

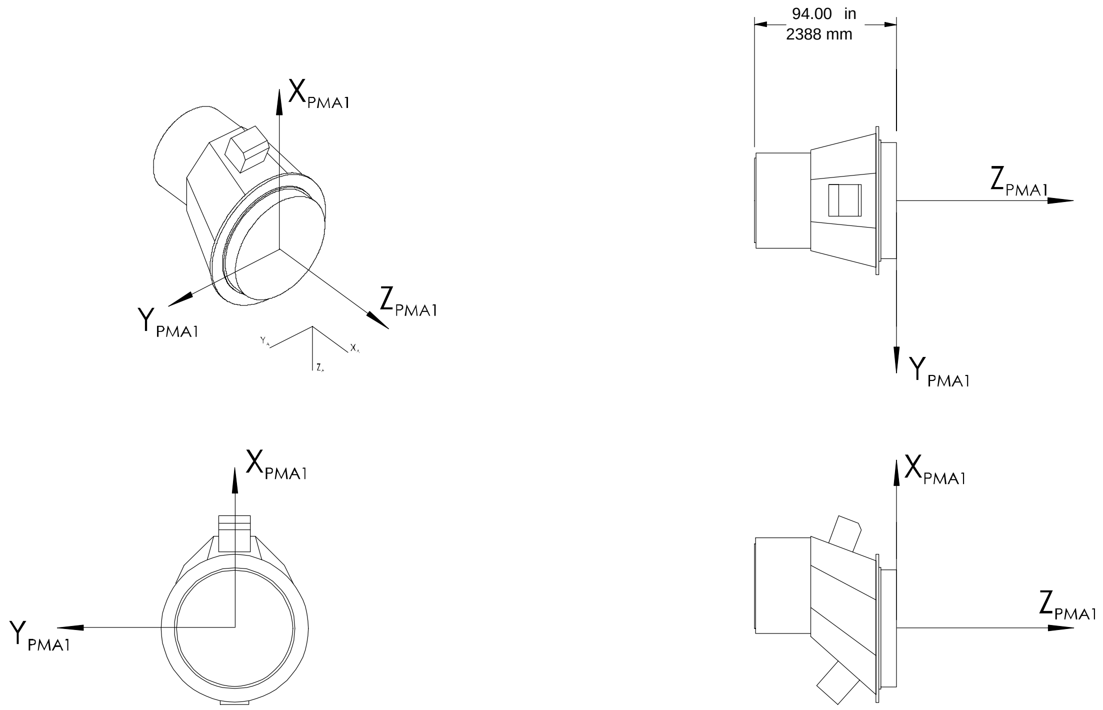
ORIENTATION: X_{APM} The X–axis is perpendicular to the nominal CBM interface plane and pierces the geometric center of the array of mating bolts at the port end of the pressurized module. The positive X–axis is toward the pressurized module from the origin.

Z_{APM} The Z–axis is parallel to the perpendicular line from the X–axis to the center of the base of the keel pin, and positive in the opposite direction as shown.

Y_{APM} The Y–axis completes the right–handed Cartesian system.

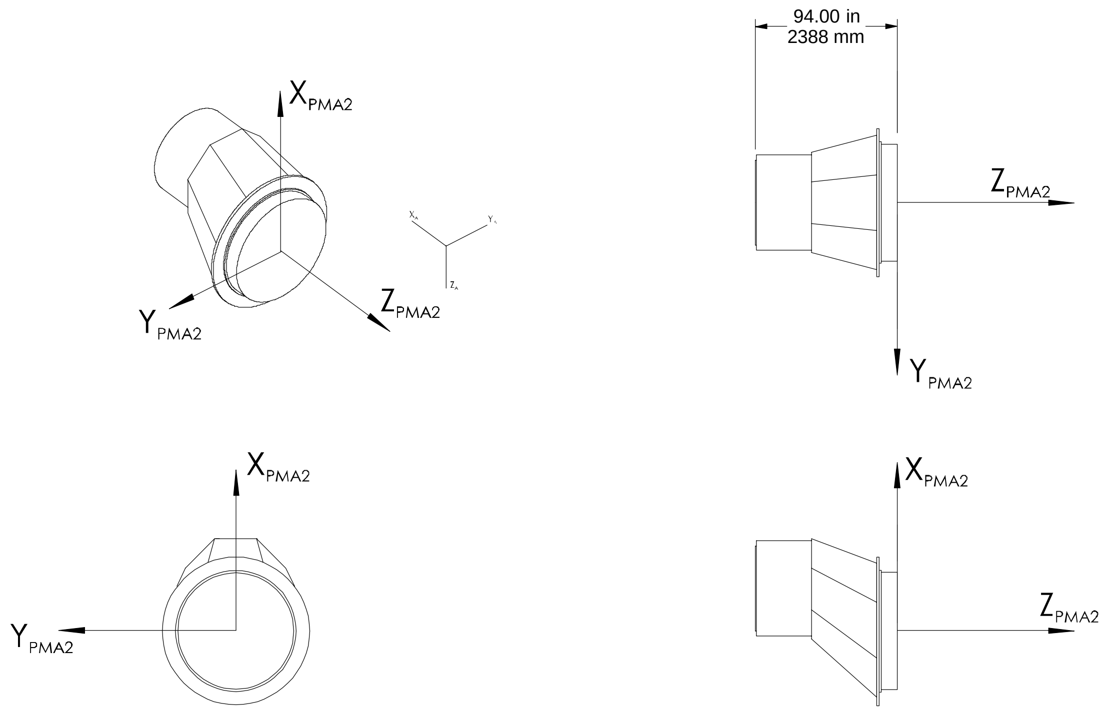
SUBSCRIPT: APM

FIGURE 9.0–14 ESA ATTACHED PRESSURIZED MODULE COORDINATE SYSTEM



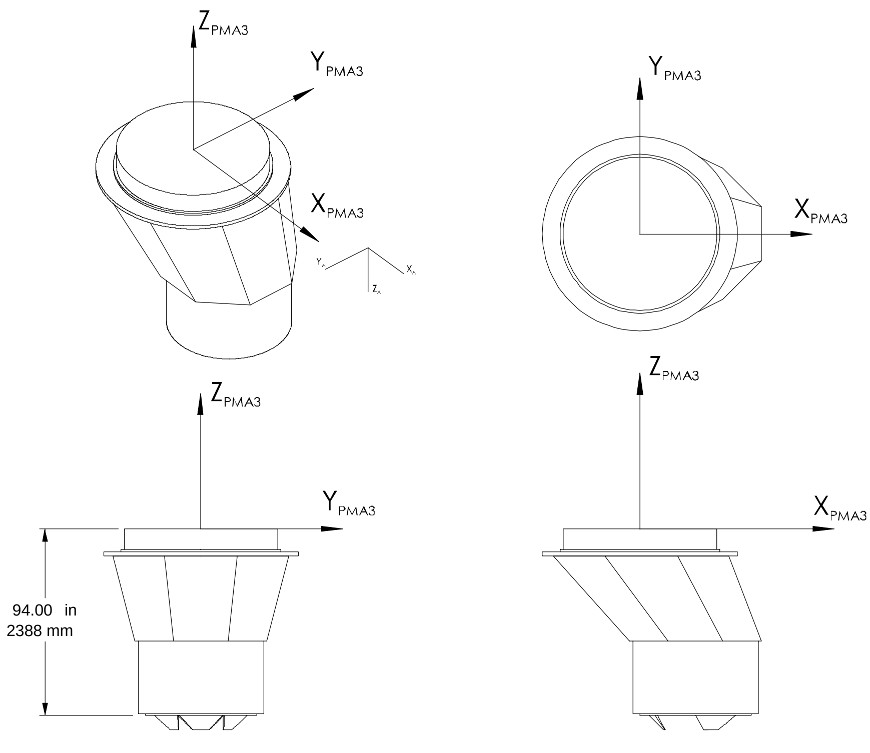
NAME:	Pressurized Mating Adapter – 1 Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located at the geometric center of the of the array of mating bolts on the interface plane of the PMA1 CBM.
ORIENTATION:	X_{PMA1} The X–axis is parallel to the perpendicular line from the Z–axis to the point midway between the centers of the zenith alignment hole and the zenith alignment pin. The positive X–axis is toward the zenith.
	Z_{PMA1} The Z–axis is perpendicular to the nominal CBM interface plane and positive out of the module as shown.
	Y_{PMA1} The Y–axis completes the right–handed Cartesian system.
SUBSCRIPT:	PMA1

FIGURE 9.0–15 PRESSURIZED MATING ADAPTER–1 COORDINATE SYSTEM



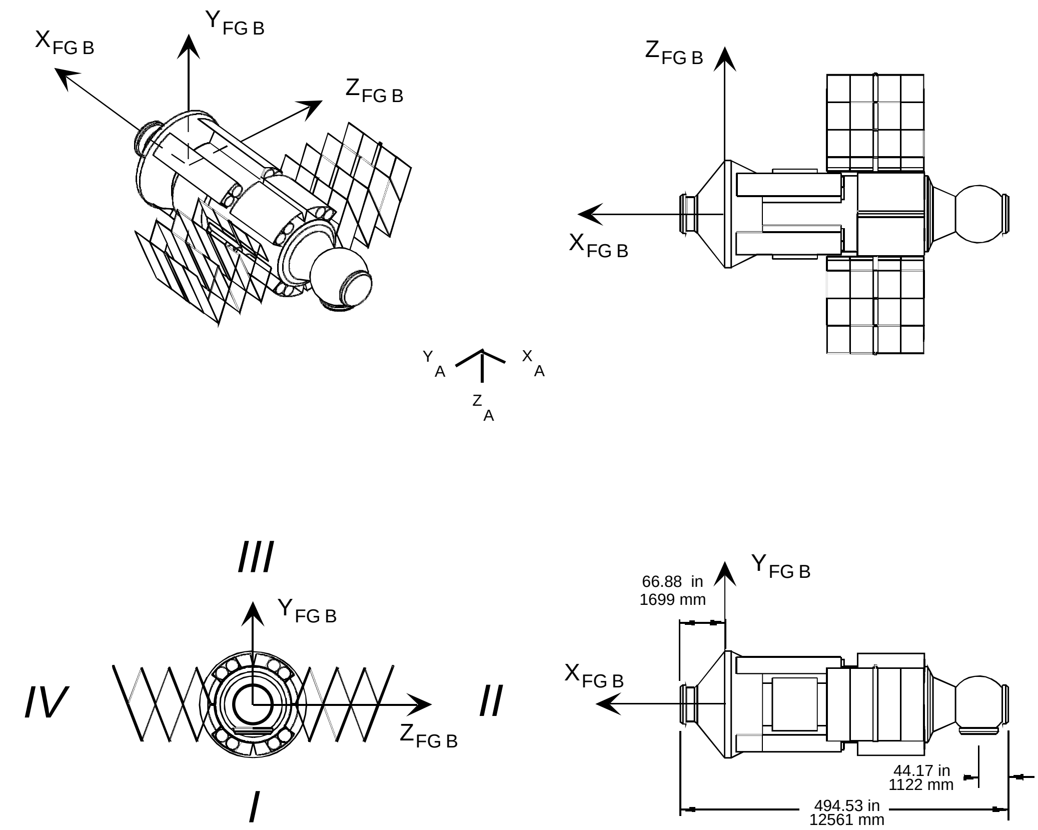
NAME:	Pressurized Mating Adapter – 2 Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located at the geometric center of the of the array of mating bolts on the interface plane of the PMA2 CBM.
ORIENTATION:	X_{PMA2} The X–axis is parallel to the perpendicular line from the Z–axis to the point midway between the centers of the zenith alignment hole and the zenith alignment pin. The positive X–axis is toward the zenith.
	Z_{PMA2} The Z–axis is perpendicular to the nominal CBM interface plane and positive out of the module as shown.
	Y_{PMA2} The Y–axis completes the right–handed Cartesian system.
SUBSCRIPT:	PMA2

FIGURE 9.0–16 PRESSURIZED MATING ADAPTER–2 COORDINATE SYSTEM



NAME:	Pressurized Mating Adapter – 3 Coordinate System
ORIGIN:	The origin is located at the geometric center of the of the array of mating bolts on the interface plane of the PMA3 CBM.
ORIENTATION:	X_{PMA3} The X–axis is parallel to the perpendicular line from the Z–axis to the point midway between the centers of the forward alignment hole and the forward alignment pin. The positive X–axis is toward the forward.
	Z_{PMA3} The Z–axis is perpendicular to the nominal CBM interface plane and positive out of the module as shown.
	Y_{PMA3} The Y–axis completes the right–handed Cartesian system.
SUBSCRIPT:	PMA3

FIGURE 9.0–17 PRESSURIZED MATING ADAPTER–3 COORDINATE SYSTEM



NAME: FGB Cargo Bloc Coordinate System

TYPE: Right–Handed Cartesian, Body–Fixed to the Pressurized Module

ORIGIN: The origin is located at the center of the nominal aft plane of the aft bulkhead.

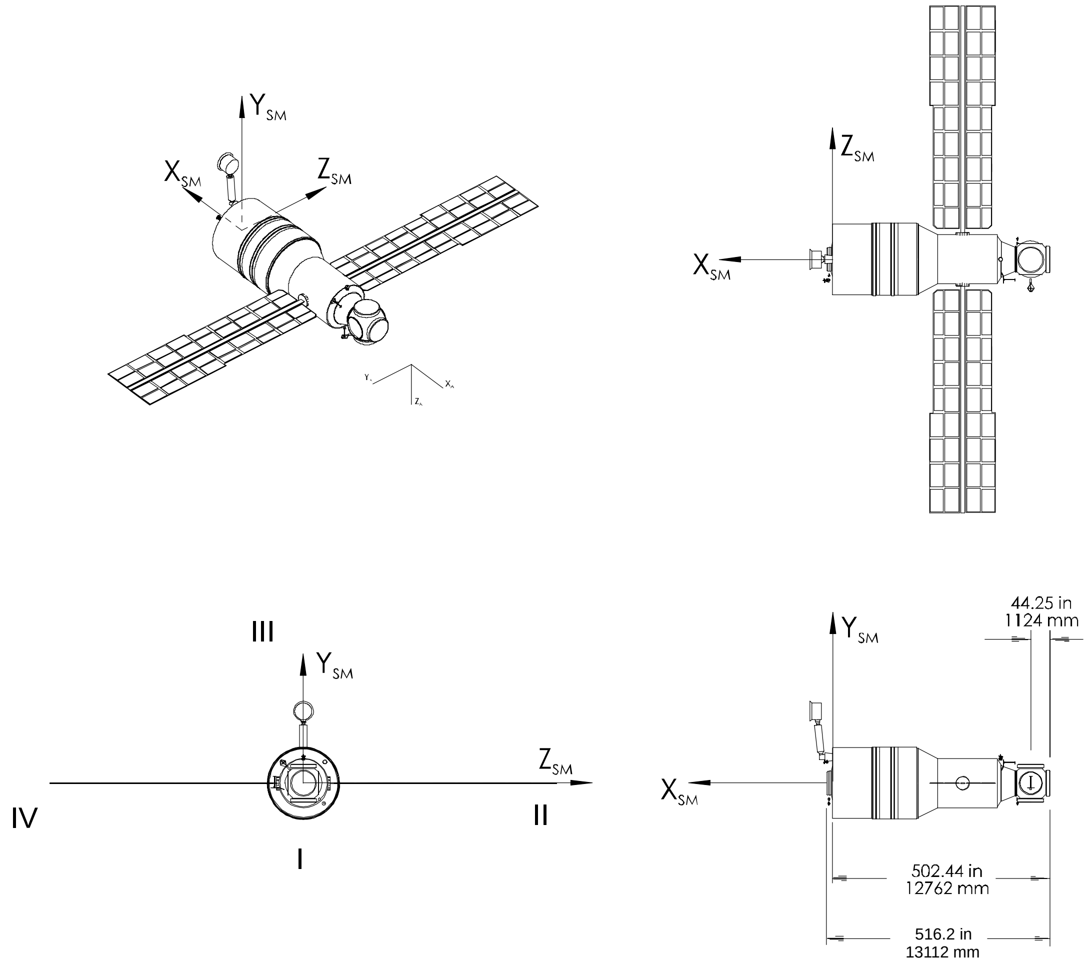
ORIENTATION: X_{FGB} The X–axis is perpendicular to the mating interface between the FGB and the PMA1 APAS, and pierces the center of that mating interface. The positive X–axis is toward the SM docking mechanism.

Y_{FGB} The Y–axis is perpendicular to the X–axis, and positive in the zenith direction as shown.

Z_{FGB} The positive Z–axis completes the right–handed Cartesian system.

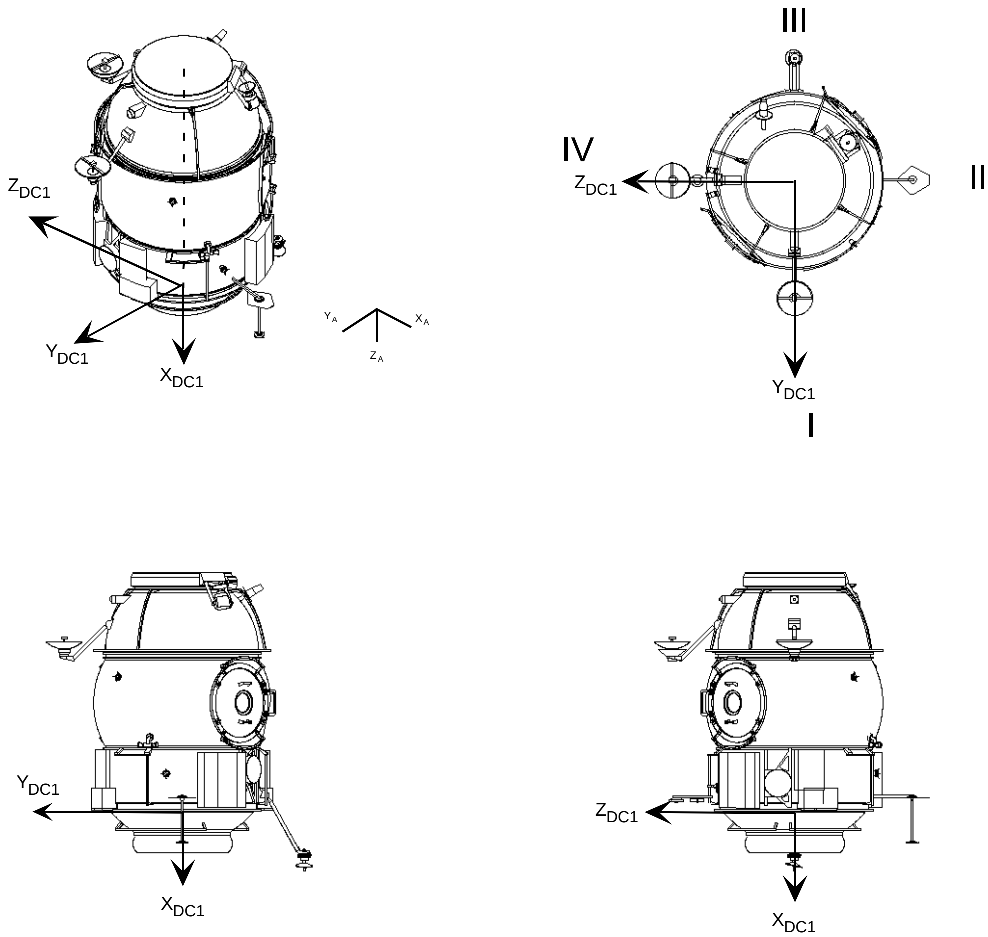
SUBSCRIPT: FGB

FIGURE 9.0–18 FGB CARGO BLOC COORDINATE SYSTEM



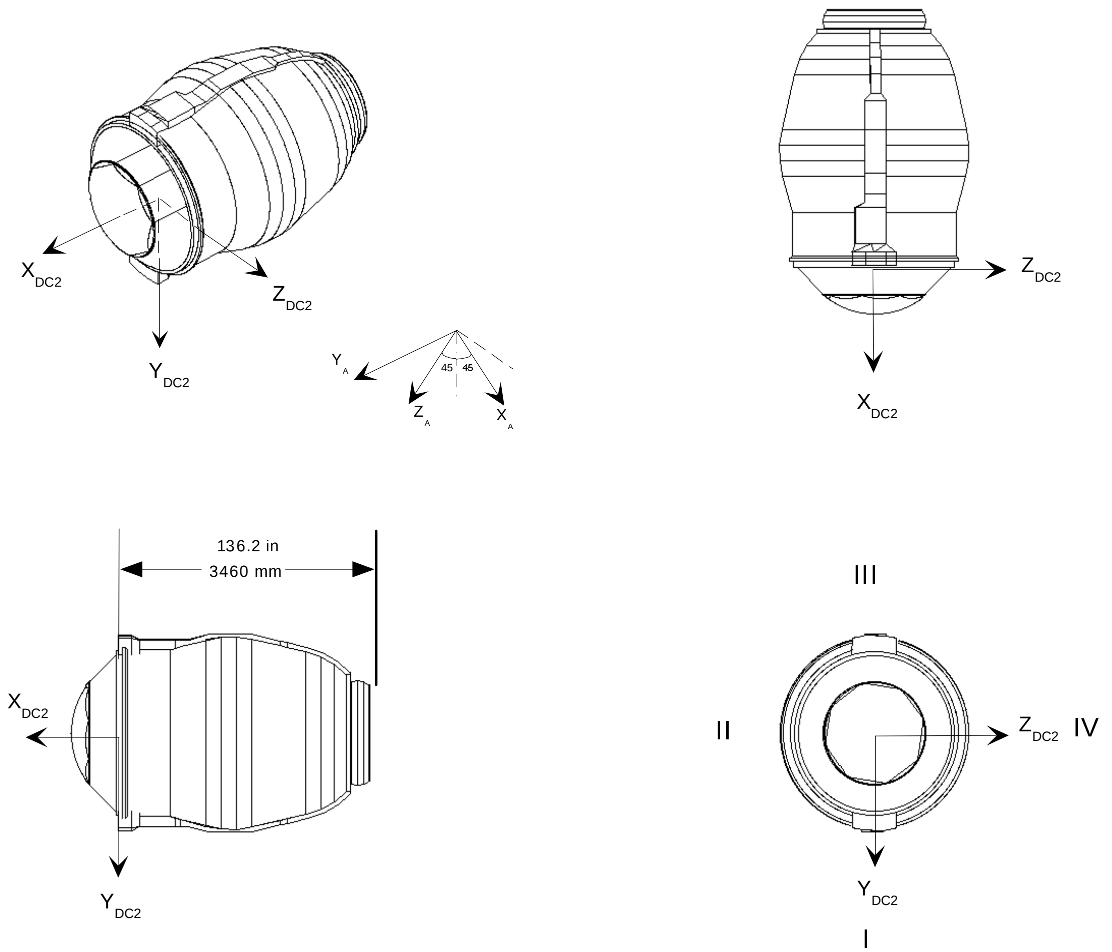
NAME:	Service Module (SM) Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located on the nominal aft plane of the aft bulkhead, at the geometric center of that bulkhead.
ORIENTATION:	X_{SM} The X–axis is perpendicular to the nominal aft plane of the aft bulkhead, and is positive toward aft
	Y_{SM} The Y–axis passes through the center of the zenith alignment pin on the aft surface of the aft bulkhead and is positive toward zenith.
	Z_{SM} The positive Z–axis completes the right–handed Cartesian system.
SUBSCRIPT:	SM

FIGURE 9.0–19 SERVICE MODULE (SM) COORDINATE SYSTEM



NAME:	Docking Compartment–1 (DC1) Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located on the nominal outboard plane of the outboard bulkhead, at the geometric center of that bulkhead.
ORIENTATION:	X_{DC1} The X–axis is perpendicular to the nominal outboard plane of the outboard bulkhead. The positive X–axis is in the direction opposite the docking cone.
	Y_{DC1} The Y–axis is parallel to the line which is perpendicular to the X–axis and which passes through the center of the designated alignment pin on the inboard surface of the docking cone bulkhead and is positive toward the alignment pin.
	Z_{DC1} The Z–axis completes the right–handed Cartesian system.
SUBSCRIPT:	DC1

FIGURE 9.0–20 DOCKING COMPARTMENT – 1 COORDINATE SYSTEM

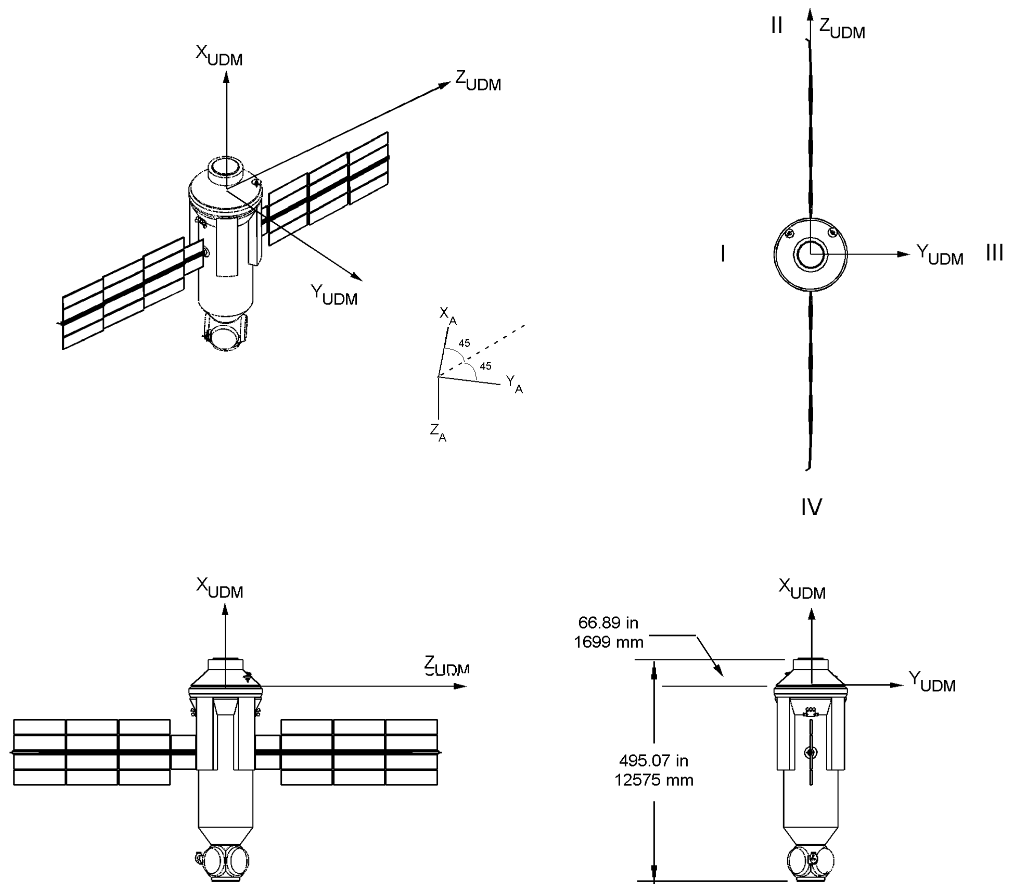


NAME:	Docking Compartment–2 (DC2) Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located on the nominal outboard plane of the outboard bulkhead, at the geometric center of that bulkhead.
ORIENTATION:	X_{DC2} The X–axis is perpendicular to the nominal outboard plane of the outboard bulkhead. The positive X–axis is in the direction opposite the docking cone.
	Y_{DC2} The Y–axis is parallel to the line which is perpendicular to the X–axis and which passes through the center of the designated alignment pin on the inboard surface of the docking cone bulkhead and is positive toward the alignment pin.
	Z_{DC2} The Z–axis completes the right–handed Cartesian system.
SUBSCRIPT:	DC2

FIGURE 9.0–21 DOCKING COMPARTMENT – 2 COORDINATE SYSTEM

FIGURE 9.0–22 DELETED

FIGURE 9.0–23 DELETED

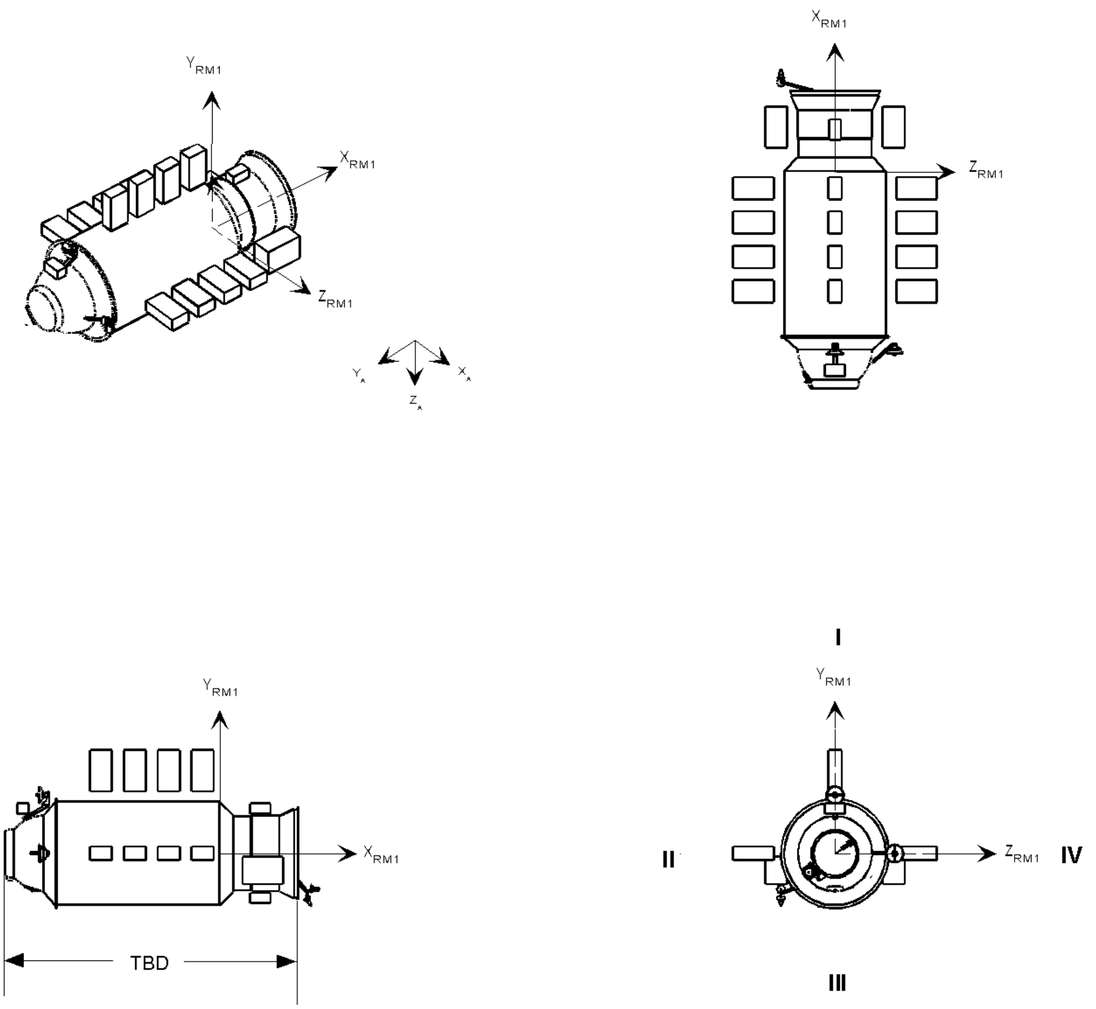


NAME:	Universal Docking Module Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located on the nominal aft plane of the aft bulkhead.
ORIENTATION:	X_{UDM} The X–axis is perpendicular to the aft mating interface between the nominal outboard plane of the outboard bulkhead. The positive X–axis is in the aft interface direction.
	Y_{UDM} The Y–axis is bisects the UDM solar array rotation axis. The positive Y–axis is in the direction of Plane III
	Z_{UDM} The Z–axis completes the right–handed Cartesian system.
SUBSCRIPT:	UDM

FIGURE 9.0–24 UNIVERSAL DOCKING MODULE COORDINATE SYSTEM

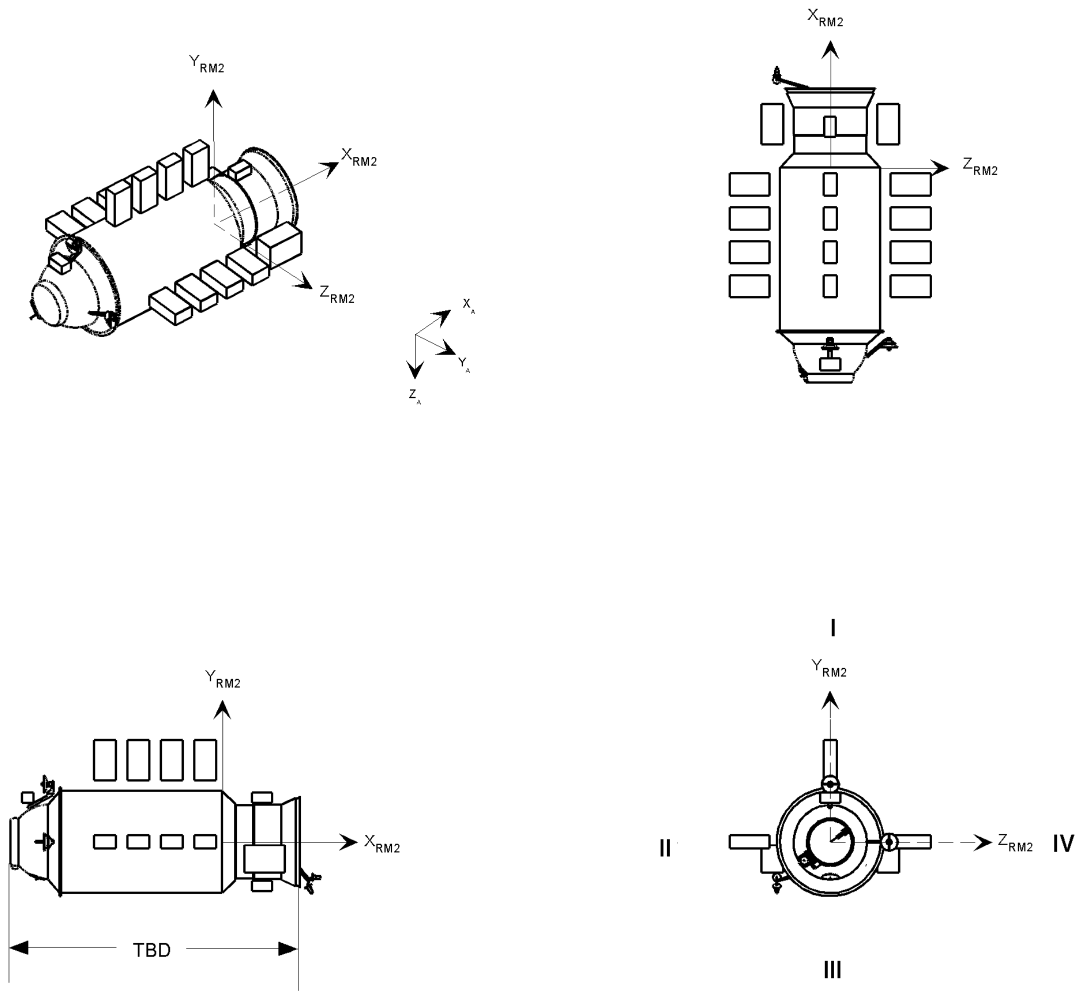
FIGURE 9.0–25 DELETED

FIGURE 9.0–26 DELETED



NAME:	Research Module –1 (RM1) Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located on the nominal outboard plane of the outboard bulkhead, at the geometric center of that bulkhead.
ORIENTATION:	X_{RM1} The X–axis is perpendicular to the nominal outboard plane of the outboard bulkhead. The positive X–axis is in the outboard direction.
	Y_{RM1} The Y–axis is perpendicular to the plane formed by the lateral experiment slots, and is positive in the direction of plane I.
	Z_{RM1} The Z–axis completes the right–handed Cartesian system.
SUBSCRIPT:	RM1

FIGURE 9.0–27 RESEARCH MODULE –1 COORDINATE SYSTEM



NAME:	Research Module –2 (RM2) Coordinate System
TYPE:	Right–Handed Cartesian, Body–Fixed to the Pressurized Module
ORIGIN:	The origin is located on the nominal outboard plane of the outboard bulkhead, at the geometric center of that bulkhead.
ORIENTATION:	X_{RM2} The X–axis is perpendicular to the nominal outboard plane of the outboard bulkhead. The positive X–axis is in the outboard direction.
	Y_{RM2} The Y–axis is perpendicular to the plane formed by the lateral experiment slots, and is positive in the direction of plane I.
	Z_{RM2} The Z–axis completes the right–handed Cartesian system.
SUBSCRIPT:	RM2

FIGURE 9.0–28 RESEARCH MODULE –2 COORDINATE SYSTEM

APPENDIX A ABBREVIATIONS AND ACRONYMS

CBM	Common Berthing Mechanism
CETA	Crew and Equipment Translational Aid
CIO	Conventional International Origin
CSA	Canadian Space Agency
CTRS	Conventional Terrestrial Reference System
EF	Exposed Facility
ELM	Experimental Logistics Module
ESA	European Space Agency
GTOD	Greenwich True of Date
ITA	Integrated Truss Assembly
ITS	Integrated Truss Segment
JEM	Japanese Experiment Module
JPDRD	Joint Program Definition and Requirements Document
LVLH	Local Vertical Local Horizontal
MBS	MRS Base System
MMD	Mobile Servicing System Maintenance Depot
MSC	Mobile Servicing Centre
MSS	Mobile Servicing System
MT	Mobile Transporter
NASA	National Aeronautics and Space Administration
NASDA	National Space Development Agency of Japan
PBM	Pressurized Berthing Module
PDGF	Power Data Grapple Fixture
PWP	Personnel Work Platform
SPDM	Special Purpose Dexterous Manipulator

SSPP	Space Station Program Participants
SSRMS	Space Station Remote Manipulator System
TCS	Thermal Control System
TDRSS	Tracking and Data Relay Satellite System
TOD	True of Date
TRRJ	Thermal Radiator Rotary Joint
UBA	Unpressurized Berthing Adapter
UCL	Unpressurized Logistics Carrier

APPENDIX B GLOSSARY

CARTESIAN SYSTEM

A system whose reference frame consists of a triad of mutually perpendicular directed lines originating from a common point in which a vector is expressed by components that are scalar magnitude projections along each axis.

DATUM POINT

The common reference location for all configuration dependent coordinate systems.

GEODETIC LOCAL VERTICAL

A reference ellipsoid of revolution that approximates the figure of the Earth is presumed. Then, the local vertical at any point is along the unique line that is normal to the ellipsoid surface and that contains the point of interest.

INERTIAL COORDINATE SYSTEM

A system whose coordinate axes are fixed, relative to the stars, at infinite distances. That is, the rotation rates about all axes, relative to the stars, are zero.

MEAN VERSUS TRUE SYSTEMS

The line of intersection of the ecliptic plane (the instantaneous plane of motion of the Earth and sun) and the celestial equatorial plane (mean Earth equator) precesses among the fixed stars with a rate of one revolution in 26,000 years. Additionally, the Earth wobbles slightly on its axis, relative to its mean position, with periods of oscillations of only a few years. The former phenomenon is called precession; the latter is called nutation. A mean–of–date system is based on the intersection of the mean equator and the plane of the ecliptic; whereas, a true–of–date system is based on the intersection of the true Earth equator and the plane of the ecliptic.

NONROTATING SYSTEMS

An inertial or quasi–inertial system. That is, any system whose rates of rotation about all axes, relative to any inertial system, are zero.

OSCULATING CONIC

A two–body approximation to non–two–body motion that is derived from conditions existing at some instant of time but that is exact only for that instant. An osculating–conic trajectory is one that is tangent to the true trajectory at the defining instant.

PERIGEE AND APOGEE

The unique points in an elliptic orbit about the Earth wherein the object achieves minimum and maximum distance, respectively, from the center of the Earth.

QUASI–INTERNAL SYSTEM

A system in which the coordinates rotate for position reference but are taken to be instantaneously fixed with respect to an inertial system for velocity reference.

ROTATING SYSTEMS

A reference frame that varies with time from an inertial system and whose rates of rotation about axes are included in transformations of velocity vectors to derive relative velocity.

SLANT RANGE

The minimum or straight–line distance between two points expressed in the same coordinate system.

SLANT RANGE–RATE

The rate of change of slant range.

APPENDIX C SUBSCRIPT DESIGNATIONS

J2000	Mean of 2000, Cartesian or Polar
M1950	Mean of 1950, Cartesian or Polar
TR	True of Date, Cartesian or Polar
GW	Greenwich True of Date, Cartesian or Polar
G	Geodetic Coordinate System
LO	Local Orbital
CTRS	Conventional Terrestrial Reference System
XPOP	XPOP Quasi–Inertial Coordinate System
OSC	Russian Orbital Coordinates System
RSO	Russian Orbital Sun Equilibrium Coordinates System
A	Analysis
R	Reference
SB	Space Station Body
RSA	RSA Analysis Coordinate System
GPS	GPS Antenna Coordinate System
O	Orbiter Coordinate System
BY	Orbiter Body Axis Coordinate System
TMV	Soyuz TM Transport Manned Vehicle Coordinate System
TCV	Progress–M Transport Cargo Vehicle Coordinate System
CRV	Crew Return Vehicle Coordinate System
SOY	Soyuz Body Axis Coordinate System
M	Progress M Body Axis Coordinate System
CTV	Crew Transfer Vehicle Coordinate System
ATV	Automated Transfer Vehicle Coordinate System
HTVS	H–II Transfer Vehicle Coordinate System, Mechanical

HTVB	H–II Transfer Vehicle Coordinate System, Attitude
SA	Starboard Solar Power/Solar Array
S4	Integrated Truss Segment S4
S5	Integrated Truss Segment S5
S6	Integrated Truss Segment S6
PA	Port Solar Power
P4	Integrated Truss Segment P4
P5	Integrated Truss Segment P5
P6	Integrated Truss Segment P6
SAW	Solar Array Wing Coordinate System
TCS	Thermal Control System
Z1	Integrated Truss Segment Z1
S0	Integrated Truss Segment S0
S1	Integrated Truss Segment S1
S3	Integrated Truss Segment S3
P1	Integrated Truss Segment P1
P3	Integrated Truss Segment P3
FGBA	FGB Array Coordinate System
SMA	SM Array Coordinate System
SPP	Science Power Platform Coordinate System
SPPR	Science Power Platform Radiator Coordinate System
SPPA	Science Power Platform Array Coordinate System
KU	Ku–Band
EAS	Early Ammonia Servicer
RACK	Rack Coordinate System
HPG	High Pressure Gas Tank ORU Coordinate System

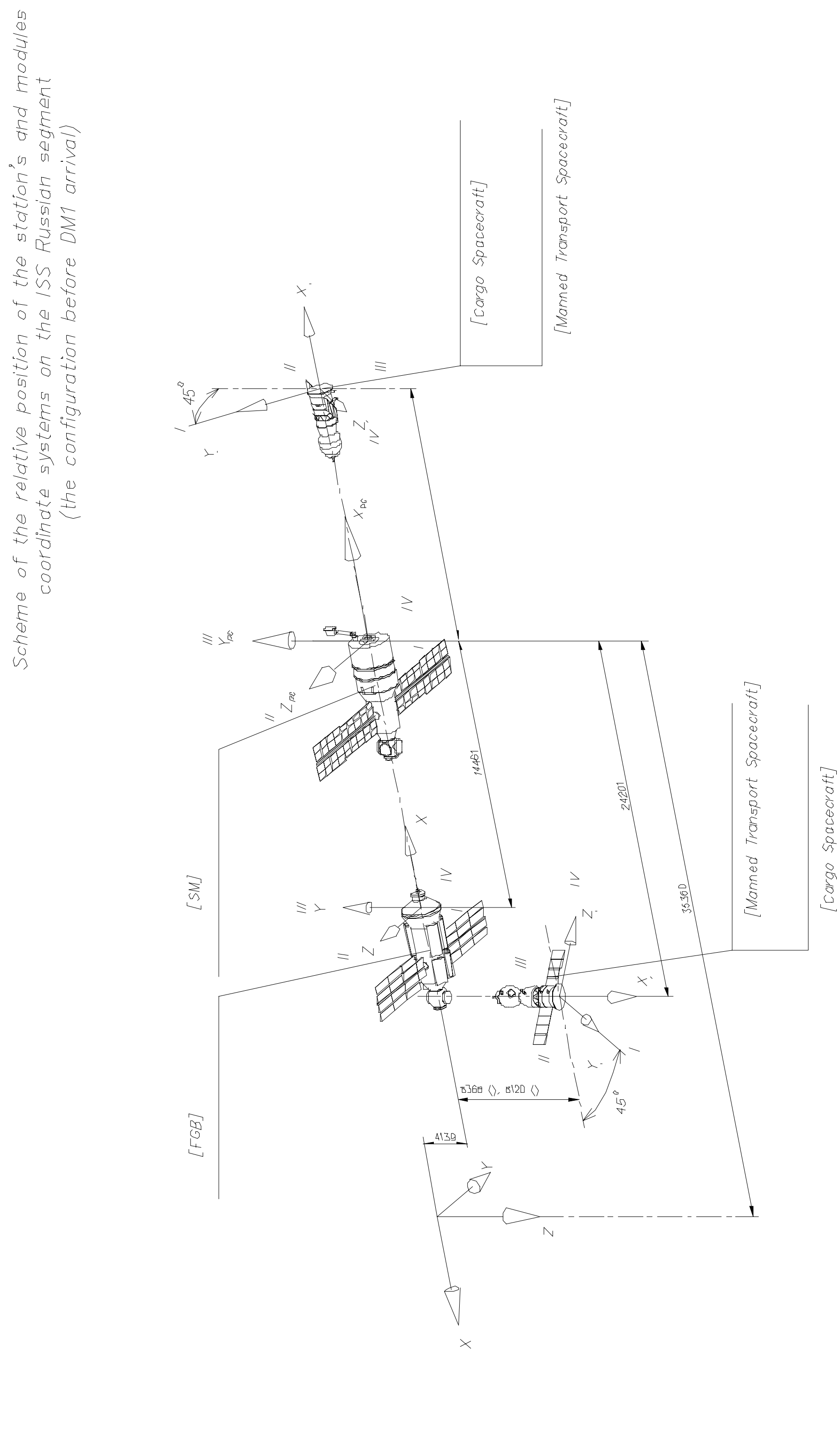
SAO	Solar Array ORU Coordinate System
PMAO	Pump Module Assembly ORU Coordinate System
S1–GBO	S1 Grapple Bar ORU Coordinate System
RORU	Radiator ORU Coordinate System
TRRJO	Thermal Radiator Rotary Joint ORU Coordinate System
MCO	Mast Canister ORU Coordinate System
SLP	Spacelab Pallet Coordinate System
ESP–2	External Stowage Platform – 2
CETA	Crew and Equipment Translational Aid
MSC	Mobile Servicing Centre
MT	Mobile Transporter
MBS	Mobile Servicing Centre Base System
OTCM	OTCM Coordinate System
EE	End Effector Operating Coordinate System
JEMRMS	JEM Remote Manipulator System Coordinate System
LAB	U.S. Laboratory Module
HAB	U.S. Habitation Module
MPLM	Mini Pressurized Logistics Module
AL	Airlock
CUP	Cupola
N1	Resource Node 1
N2	Resource Node 2
N3	Resource Node 3
CAM	Centrifuge Accommodation Module Coordinate System
JEM	Japanese Experiment Module
ELM–PS	Experimental Logistics Module, Pressurized Section

ELM–ES	Experimental Logistics Module, Exposed Section
EF	Exposed Facility
APM	ESA Attached Pressurized Module
PMA1	Pressurized Mating Adapter 1 Coordinate System
PMA2	Pressurized Mating Adapter 2 Coordinate System
PMA3	Pressurized Mating Adapter 3 Coordinate System
FGB	FGB Cargo Bloc Coordinate System
SM	Service Module Coordinate System
DC1	Docking Compartment 1 Coordinate System
DC2	Docking Compartment 2 Coordinate System
UDM	Universal Docking Module Coordinate System
RM1	Research Module 1 Coordinate System
RM2	Research Module 2 Coordinate System

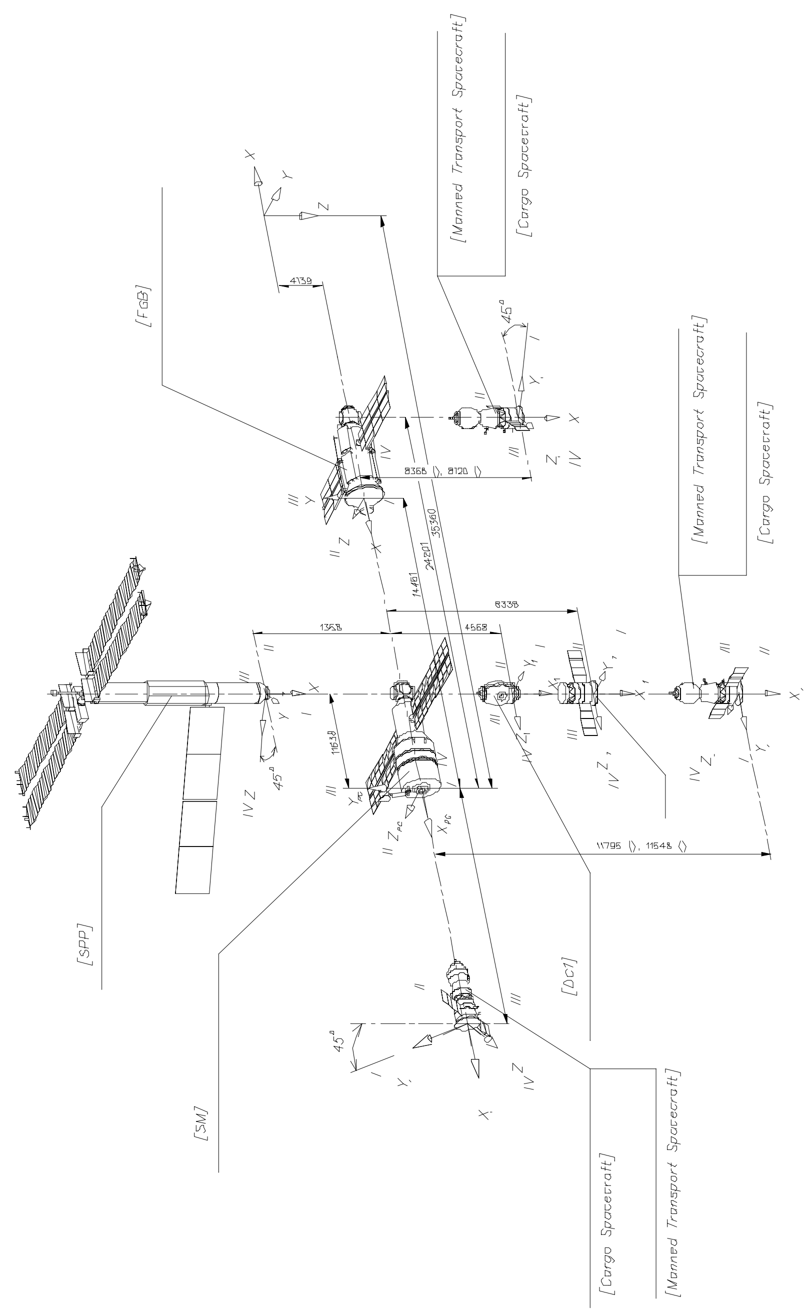
APPENDIX D REFERENCE AND SOURCE DOCUMENTS

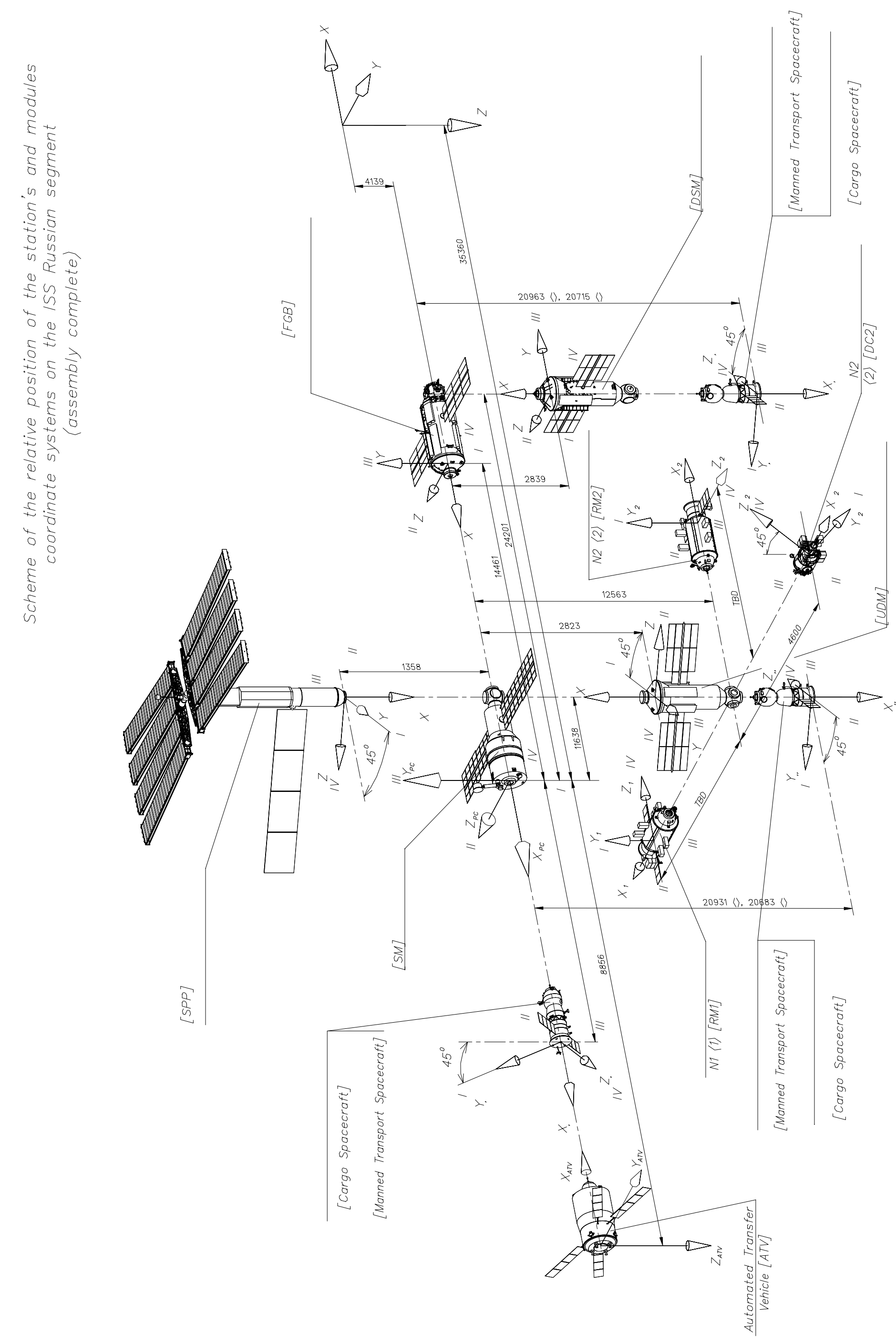
U.S. Naval Observatory Circular No. 163, December 10, 1981 Reference	The International Astronomical Union Resolutions on Astronomical Constants, Time Scales, and the Fundamental Reference Frame Figure 3.0–1
U.S. Naval Observatory Reference	International Earth Rotation Service Bulletin–A Figure 3.0–12
NSTS 07700, Vol. IV Attachment 1, ICD–2–19001 Reference	Shuttle Orbiter/Cargo Standard Interfaces Figure 4.0–5

APPENDIX E   ISS RUSSIAN SEGMENT


Scheme of the relative position of the station's and modules
coordinate systems on the ISS Russian segment
(the configuration before DM1 arrival)
[Cargo Spacecraft]
[Manned Transport Spacecraft]
[SM]
[FGB]
14461
24201
36360
4139

Scheme of the relative position of the station's and modules coordinate systems on the ISS Russian segment (the configuration before UDM arrival)




Scheme of the relative position of the station's and modules coordinate systems on the ISS Russian segment
(assembly complete)
[SPP]
[SM]
[FGB]
[DSM]
[Manned Transport Spacecraft]
[Cargo Spacecraft]
N2 (2) [DC2]
N2 (2) [RM2]
[UDM]
N1 (1) [RM1]
[Manned Transport Spacecraft]
[Cargo Spacecraft]
[Cargo Spacecraft]
[Manned Transport Spacecraft]
Automated Transfer Vehicle [ATV]
4139
35360
20963 (), 20715 ()
2839
24201
14461
12563
2823
1358
11638
4600
TBD
20931 (), 20683 ()
8856
45°