Three Dimensional Flex Hose

by
Peter F. Low and Charles F. Emki
Lockheed Martin Astronautics
Denver, Colorado

Abstract

The flexible hose designs used for Titan launch vehicle air conditioning umbilicals were based on experience, not finite element analyses. At launch, the umbilical is pulled loose; and the hose's motion then becomes a three-dimensional, large-amplitude, flexible-body dynamics problem.

On a recent launch, the videos showed a problem of the umbilical recontacting the launch vehicle. For this reason, Martin Marietta (now a subsidiary of Lockheed Martin) developed three-dimensional ADAMS simulations both to predict the recontact behavior and to verify that a design change maintains acceptable clearance. The presentation includes videos comparing the simulations with observations from four different configurations of umbilical geometry. Details of the modeling approach, the analysis parameters and the comparisons of analyses results with actual behavior are described.

Three Dimensional Flexible Hose

by:

Peter Low and Charlie Emki

Martin Marietta Technologies, Inc.

Launch Systems Center of Excellence

Phone: 303 / 977-5102 **Fax: 303 / 971-2599**

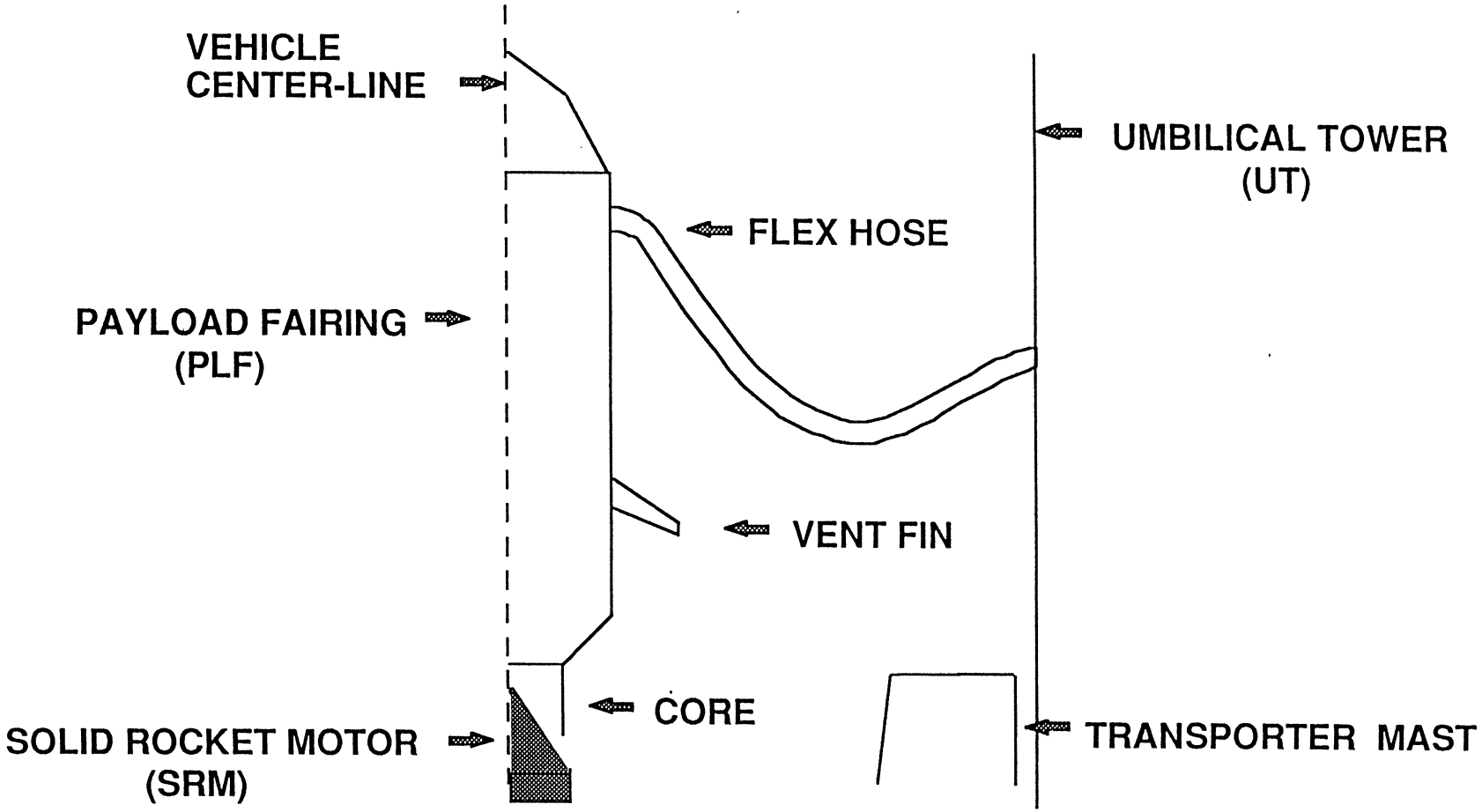
3D Flexible Hose

Introduction

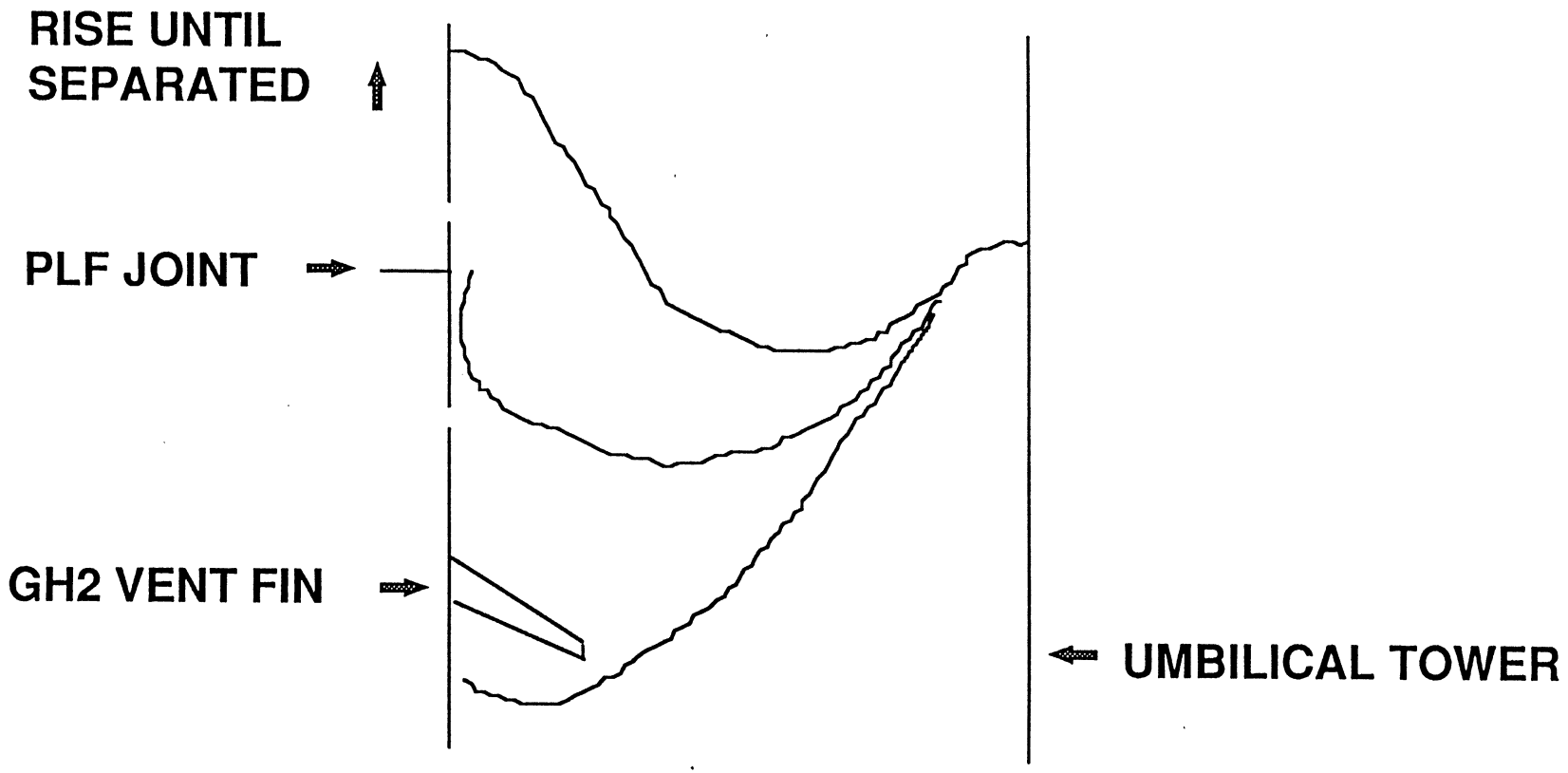
- In the past the A/C Flexible Hose (umbilical) designs for the Titan IV were based on experience. They were not FE modeled.
- The flex hose system designs are three-dimensional, large-displacement, flexible-body dynamics problems.
- During a launch an umbilical recontacted a payload fairing. For this reason Martin Marietta Technologies, Inc. developed a model.
- The model has been used to predict flex hose problems and fixes for them. The model was validated and the fixes incorporate.
- Details of the modeling approach and analyses are discussed.
- A video comparing predicted hose dynamics to actual hose dynamics during Titan IV launches is shown.

A/C Hose Configuration

Side View (Perpendicular to the Plane of the Flex Hose, *Umbilical*)

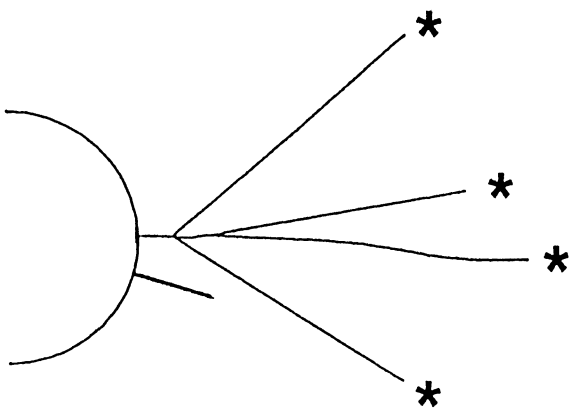


A/C Hose Recontact

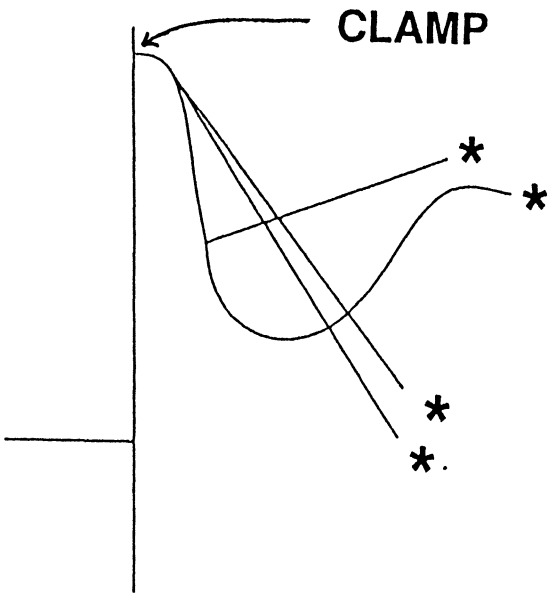


UMBILICAL SYSTEM COMPONENTS

TOP VIEW



SIDE VIEW



* UMBILICAL TOWER OR TRANSPORTER MAST

LANYARDS: --- PRIMARY --- SECONDARY --- RESTRAINT

--- UMBILICAL --- VENT FIN — PAYLOAD FAIRING JOINT

3D Flexible Hose Development

PARAMETERS

- Derived from:
  - Ground Facilities
  - Hose
  - Vehicle
  - Configuration

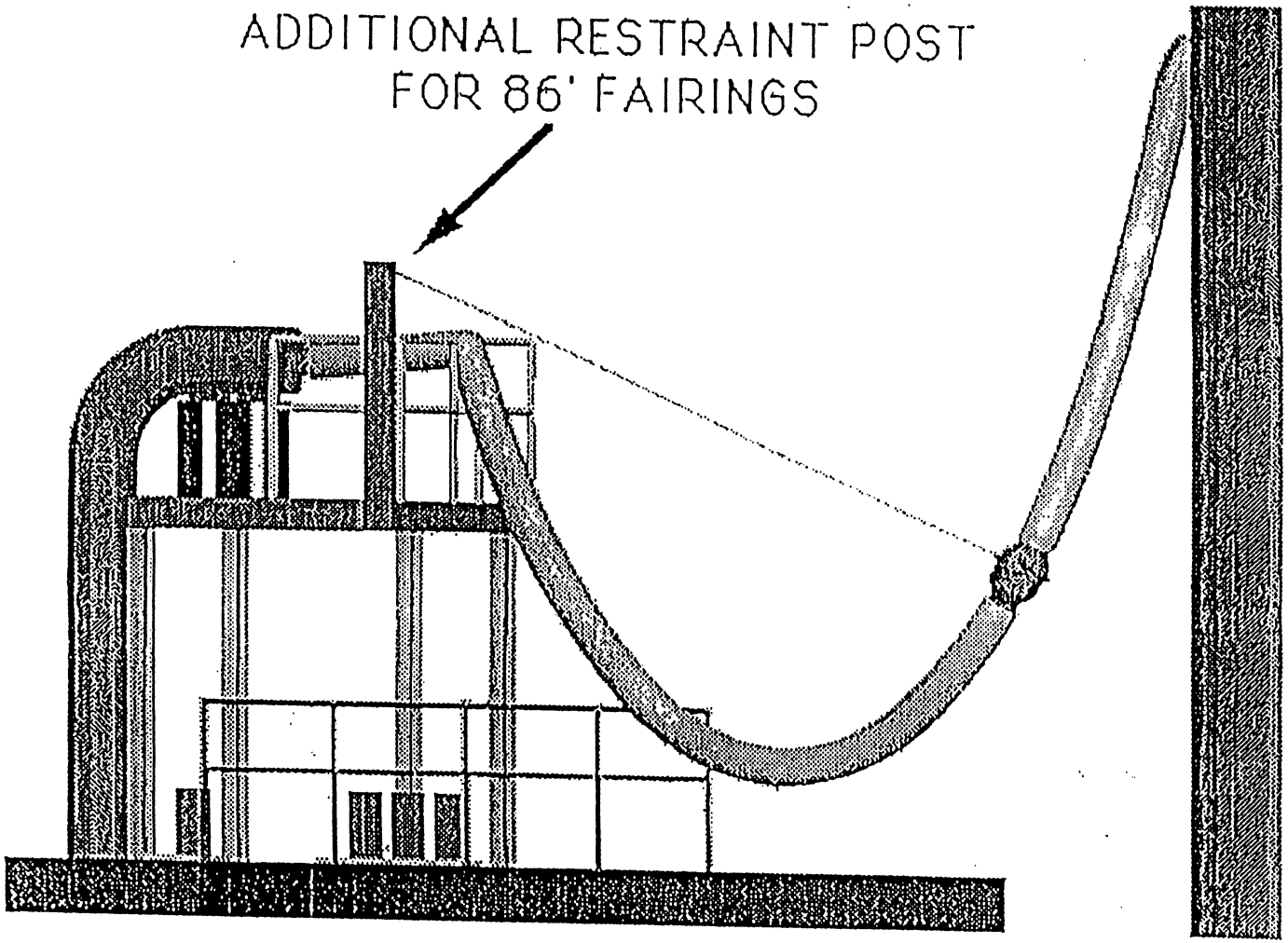
- Analyses of:
  - Variability
  - Limits
  - Ways to Model These Effects
  - Grouping

3D Flexible Hose Development

Engineering Technologies

- Thermal
- Materials
- Flex Hose Build
- Aerodynamics
- Airborne Engineering
- Ground Engineering
- Trajectory Dynamics
- Process & Control
- Dynamics Modeling

3D Umbilical Model Details

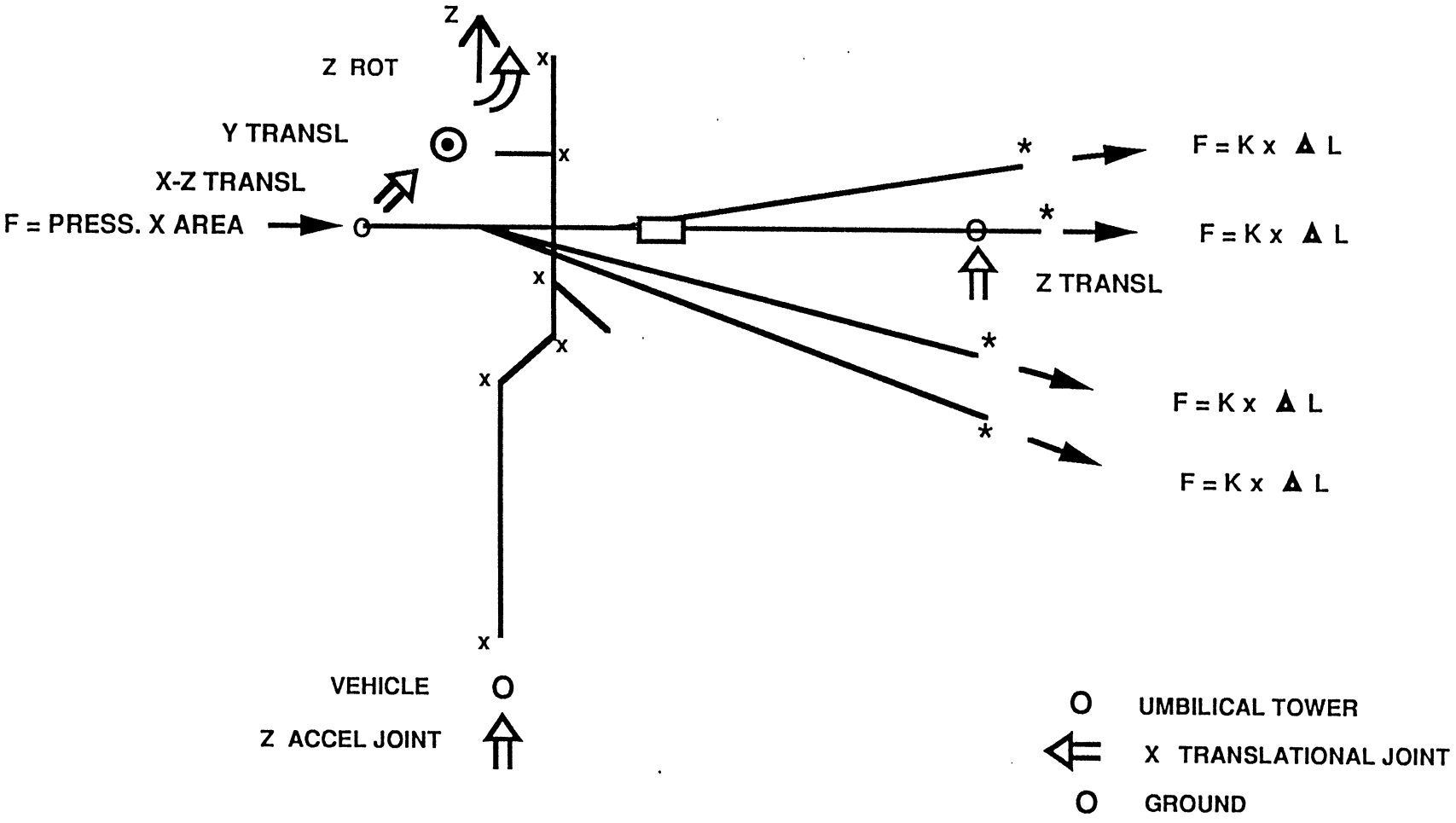


3D Umbilical System Model

SYMBOLS

x	FIXED POINTS ON THE VEHICLE (PART)
*	FIXED POINTS ON UMBILICAL TOWER (PART)
⊙ , ⇑	TRANSLATIONAL JOINT
分	ROTATIONAL JOINT
O	PART (MASS, MOTION OR FIXED STRUCTURE)
→	FORCE
→	AXIS

3D Umbilical System Model



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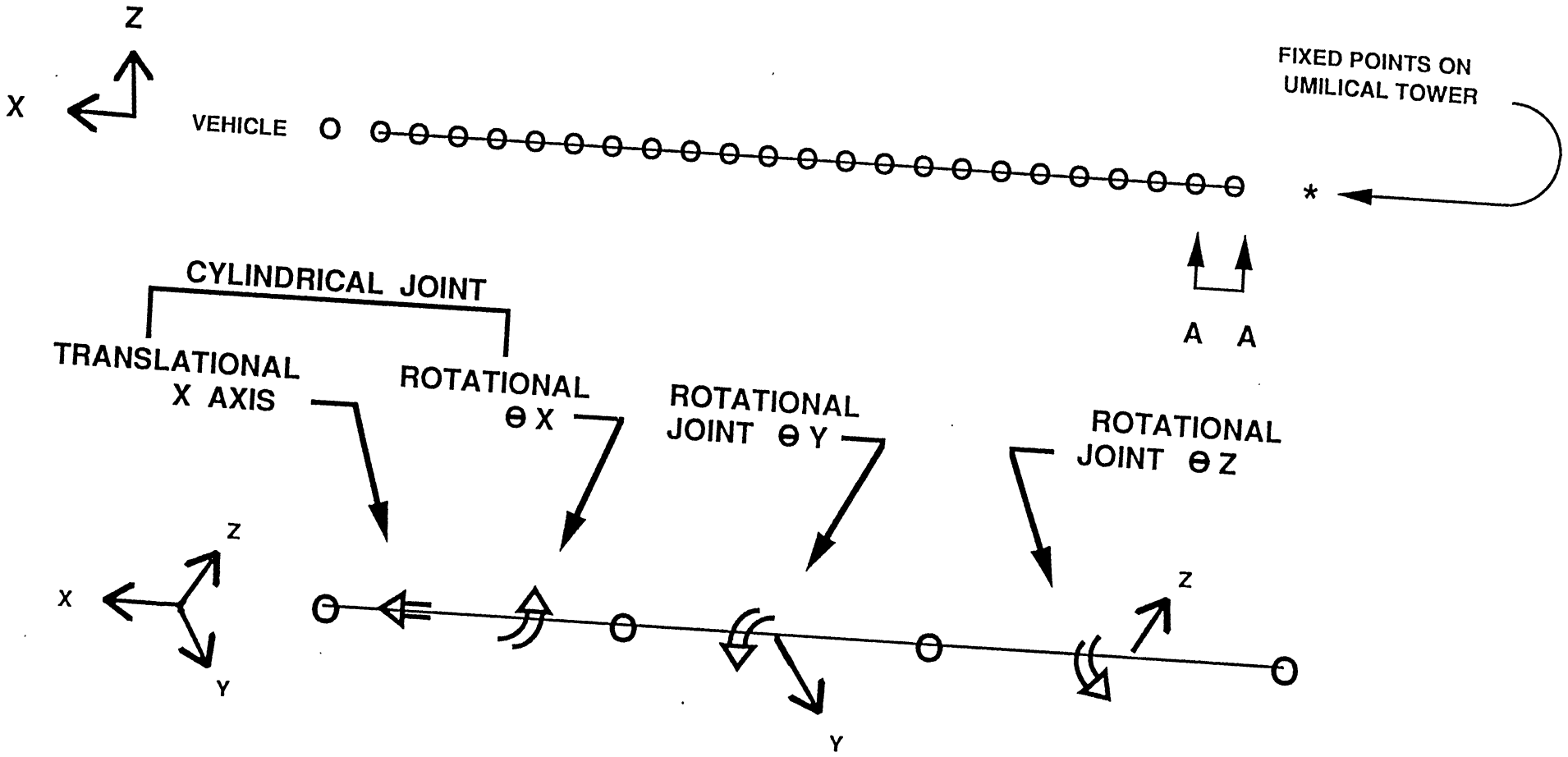
3D Umbilical Model Details

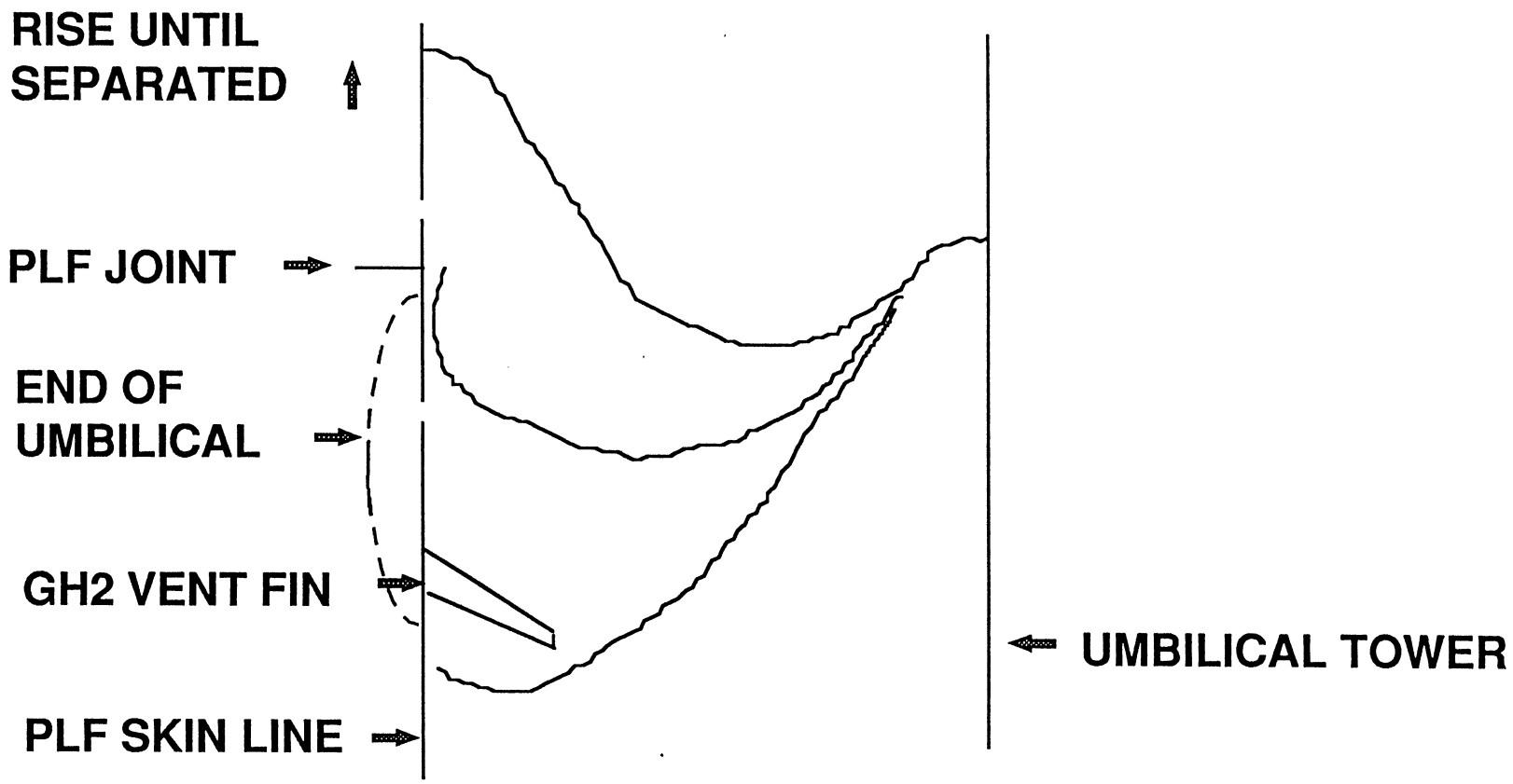


VIEW A -- A

Philosophy of Verification

- Calculations
- Studies
- Modeling
- Comparison
- Controls

Flight vs Prediction of A/C Umbilical Recontact



Video of Flex Hose (Umbilical) Dynamics

I 86 ft. PLF at Launch Complex 41
- a. Flight Video Recontact
- b. Prediction for Flight
- c. Prediction for Flight with a Restraint Lanyard

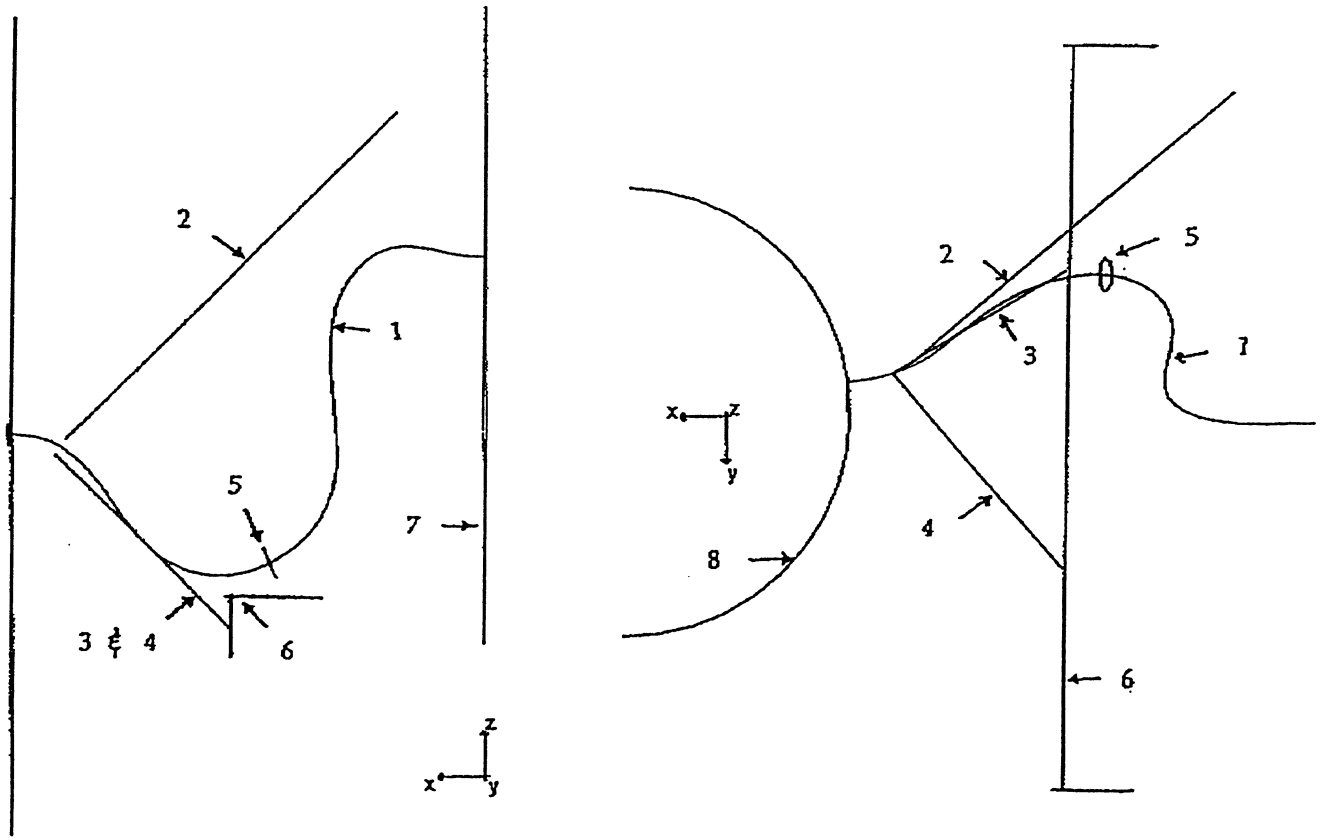
II 76 ft. PLF at Launch Complex 41
- a. Flight Video
- b. Prediction for Flight

III 76 ft. PLF at Launch Complex 40
- a. Flight Video
- b. Prediction for Flight

IV 56 ft. PLF at Launch Complex 40
- a. Viewgraphs
- b. Prediction for Flight
- c. Prediction for Flight with a Restraint Lanyard
- d. Flight Video with a Restraint Lanyard

The First A/C Umbilical Flown with a Restraint Lanyard

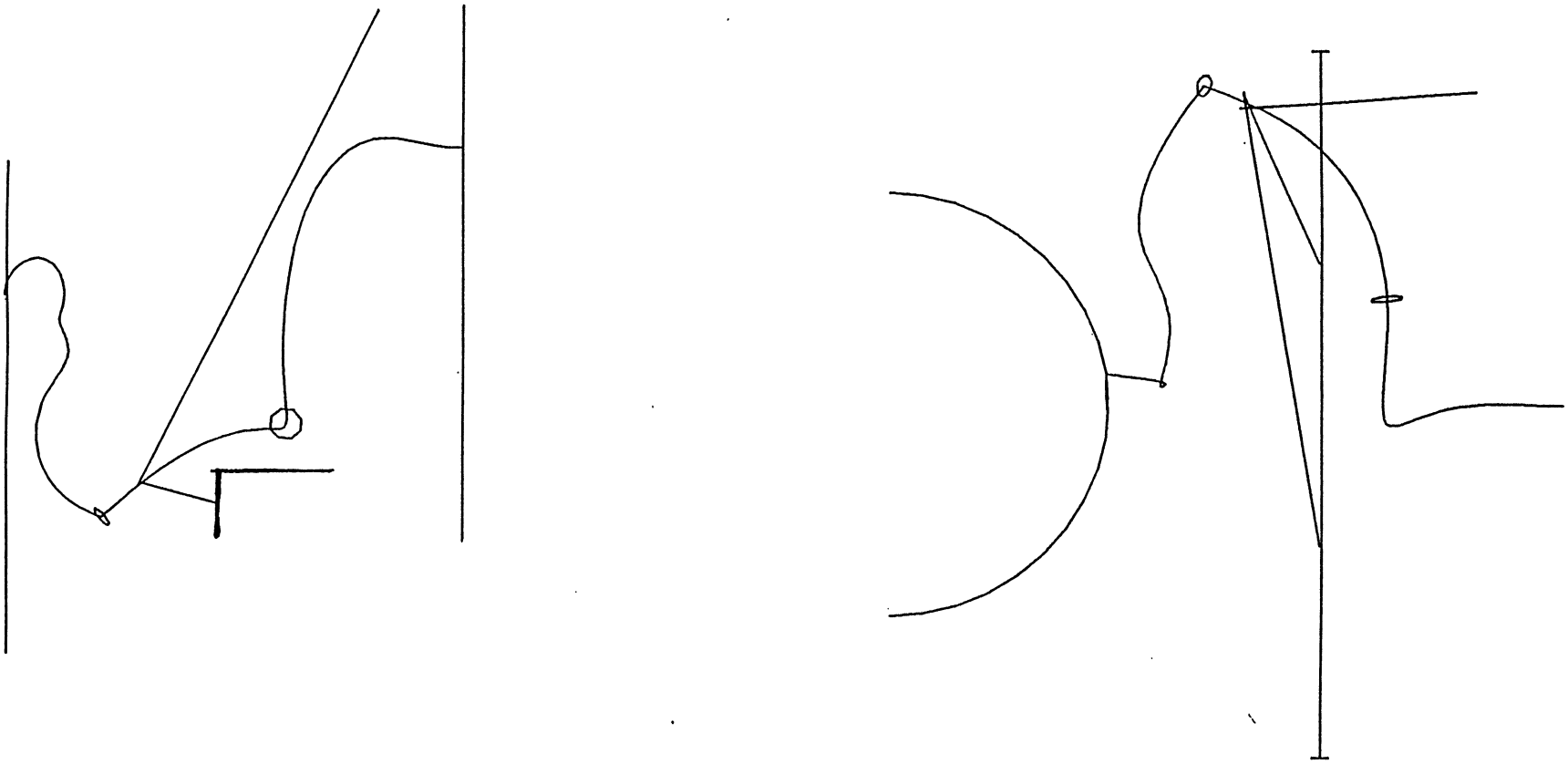
CONFIGURATION



ID	COMPONENT
1	UMBILICAL
2	RESTRAINT LANYARD
3	PRIMARY LANYARD
4	SECONDARY LANYARD
5	RF CAN
6	TRANSPORTER MAST
7	UMBILICAL TOWER
8	PAYLOAD FAIRING

The First A/C Umbilical Flown with a Restraint Lanyard

UMBILICAL DYNAMICS



---- TRACE OF THE OPEN END OF THE UMBILICAL

Model Validation

- DEFINITION

  The Umbilical System Model is Validated if It Accurately Duplicates the Dynamics of the Umbilical in All Configurations.

- CONCLUSION
  - The Model Provided a Dynamics Match with Primary and Secondary Umbilical Releases for Multiple Configurations.
  - Lockheed Martin and the Air Force Have Concluded the Model Should Be Used to Analyze All A/C PLF Umbilicals for which Recontact is considered possible.
  - Our Familiarity with ADAMS Allowed Us to Develop a Model with the Desired Unique Properties and Optimize it Quickly.

Reasons for Using ADAMS

- Provides Fast Solutions of Complex Problems
- Increases Total Number of Variables that Can Be Analyzed
- Allows Nonlinear Characterization of Inputs
- Easily Creates Graphics for Checking the Effects of Parameters
- Allows Results to be Optimized Quickly

Recommended Improvements

The Addition of the Following Capabilities Will Make It Easier to Solve Flex Hose and Cable Problems

1 A Four DOF Joint (three rotations and a translation joint) that will allow linear and nonlinear stiffness and damping.

2 An Independent property statement (linear and nonlinear) that can be called by Force Elements.

3 The ability to automatically generate a series of (Parts, Markers, Joints and Forces) in View.