Peacekeeper Tank Slash Model

Material Presented by

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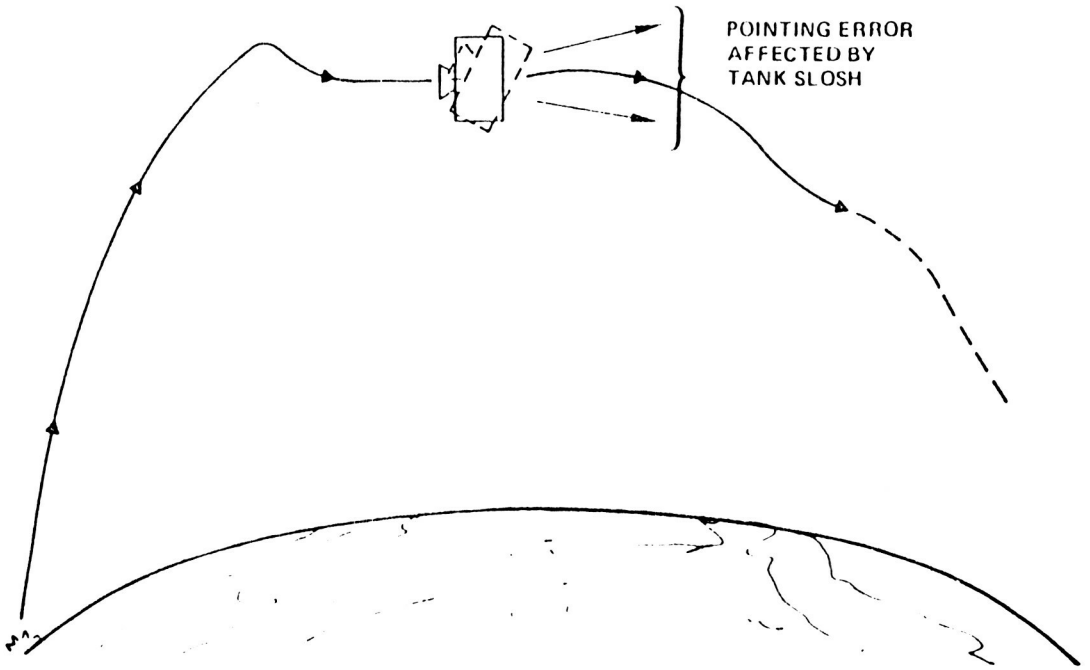
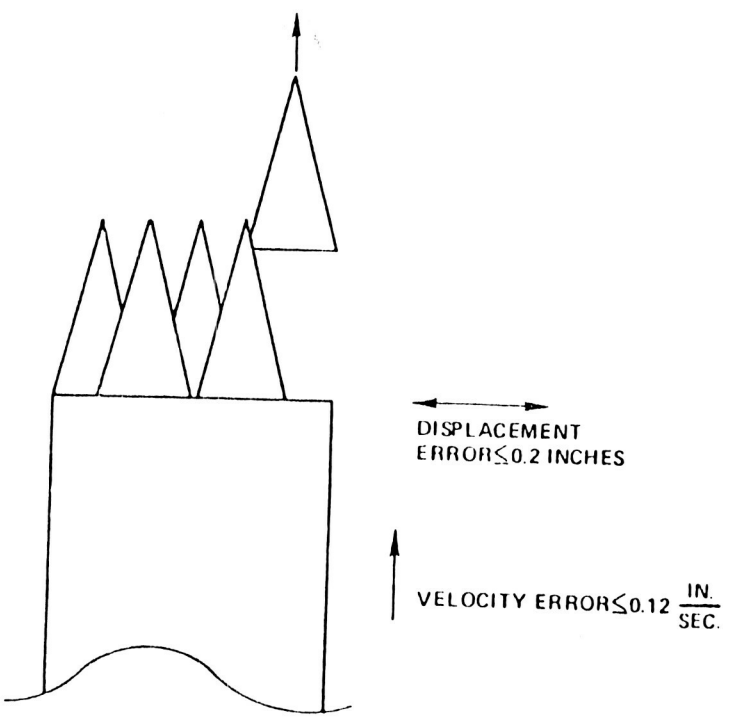
Rocketdyne Division

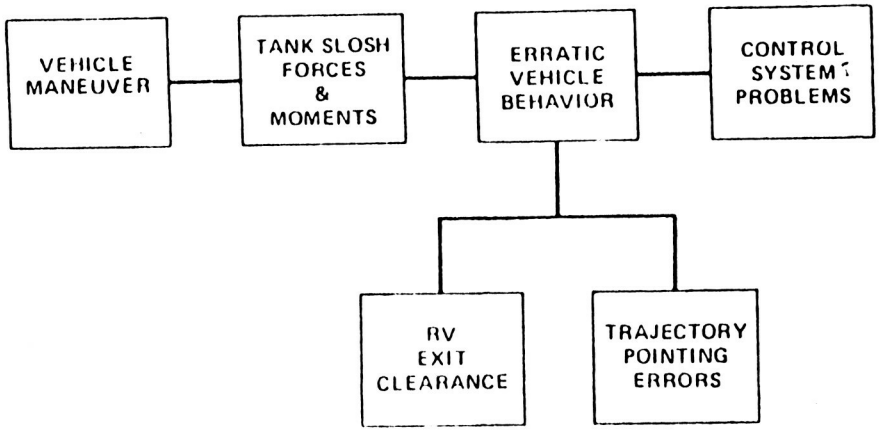
MOTIVATION FOR ANALYZING SLOSH IN PEACEKEEPER



ALLOWABLE VEHICLE ERRORS FOR NOSE CONE EJECTION CLEARANCE



VEHICLE MANEUVER - SLOSH PROBLEM



CURRENT MODELS UNSUITABLE

- PENDULUM MODEL (MMA) NOT APPLICABLE IN
  - ZERO G
  - BAFFLED TANKS
- SOLA-VOF MODEL (MDAC) INSUFFICIENT
  - 2-D (3-D NECESSARY)
  - STAIR STEP TANK WALLS
  - NO BAFFLE/SCREEN RESISTANCE

SOLA SLOSH MODEL

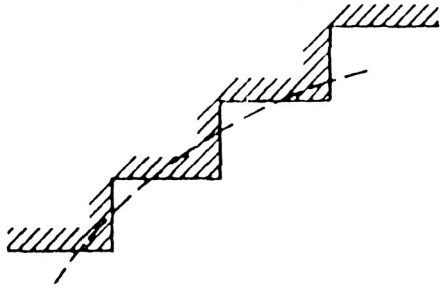
- **DEVELOPED BY FLOW SCIENCES INC. FOR ROCKETDYNE TO HANDLE:**
  - 3-D NAVIER STOKES EQUATIONS IN FINITE DIFFERENCE FORM
  - MULTIPLE FREE SURFACES
  - VISCOUS FLUID
  - LIMITED COMPRESSIBILITY
- **MODEL ACCOMMODATES:**
  - GENERALIZED OBSTACLES
  - POROUS BAFFLES
  - CURVED WALL SIMULATION
  - GENERALIZED ROUTINE FOR INPUT OF MOTION FORCING FUNCTIONS
- **MODEL CALCULATES TANK FORCES AND MOMENTS CAUSED BY LARGE AMPLITUDE SLOSH**

SLOSH FORCE/MOMENT PREDICTION DEPENDS ON

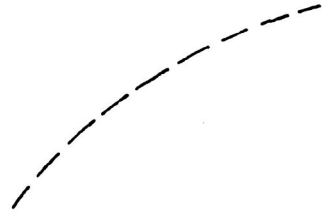
- **INITIAL FREE SURFACE CONFIGURATION**
- **AMOUNT OF LIQUID IN TANK (PERCENT FILL)**
  - INTERNAL TANK GEOMETRY (INCLUDING BAFFLES)
  - LIQUID PROPERTIES
  - PAST HISTORY OF MANEUVER (INSTANTANEOUS VELOCITY AND DISPLACEMENT FIELDS OF LIQUID)

SOLA SLOSH SURFACE SPECIFICATION

- GENERATORS PERMIT USER TO SPECIFY GEOMETRY OF TANK WALLS AND BAFFLE LOCATIONS
- WALL SURFACES ARE SMOOTH RATHER THAN STEPPED (REPRESENTED BY VOF ALGORITHM)– MUCH BETTER WALL FORCE PREDICTIONS



EARLIER MODELS

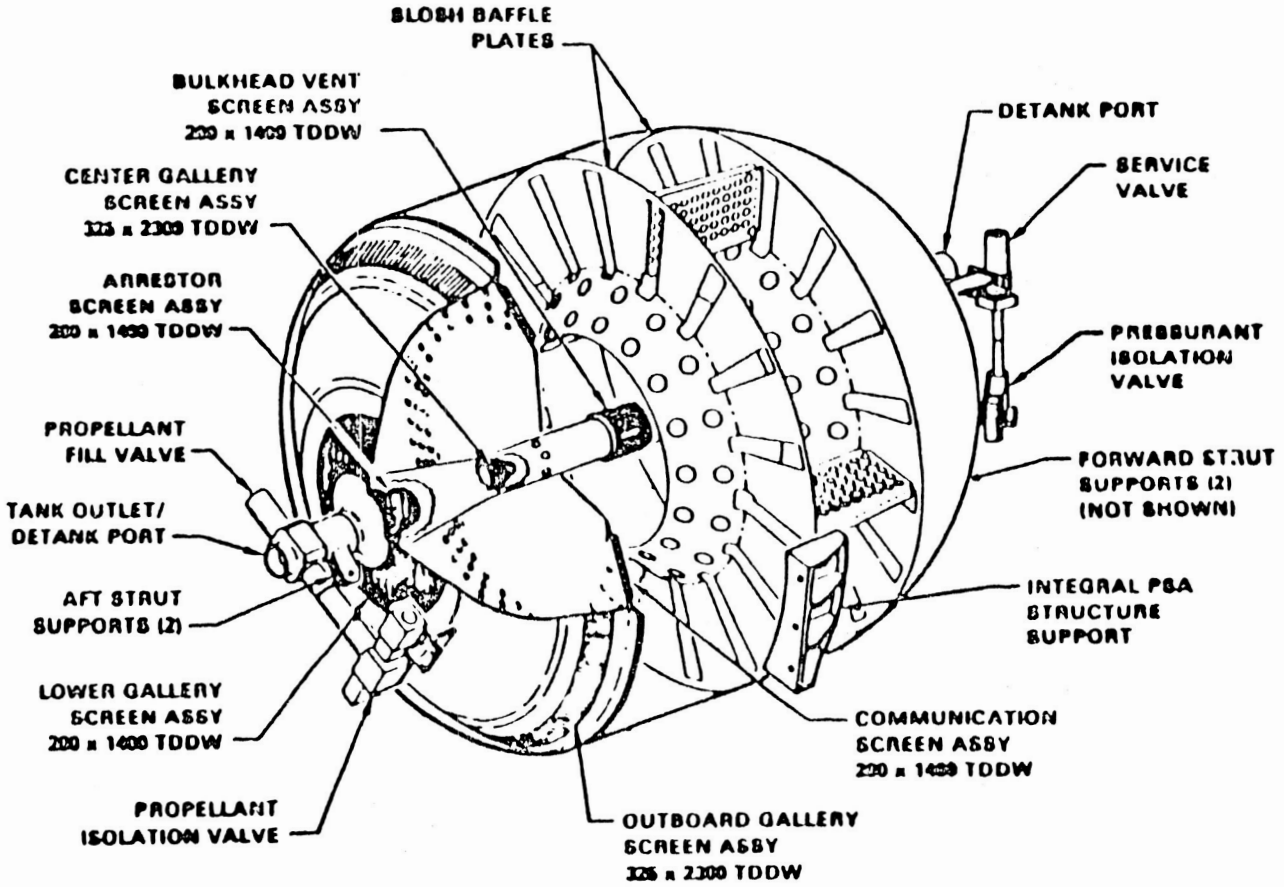


SOLA SLOSH

CODE VALIDATION

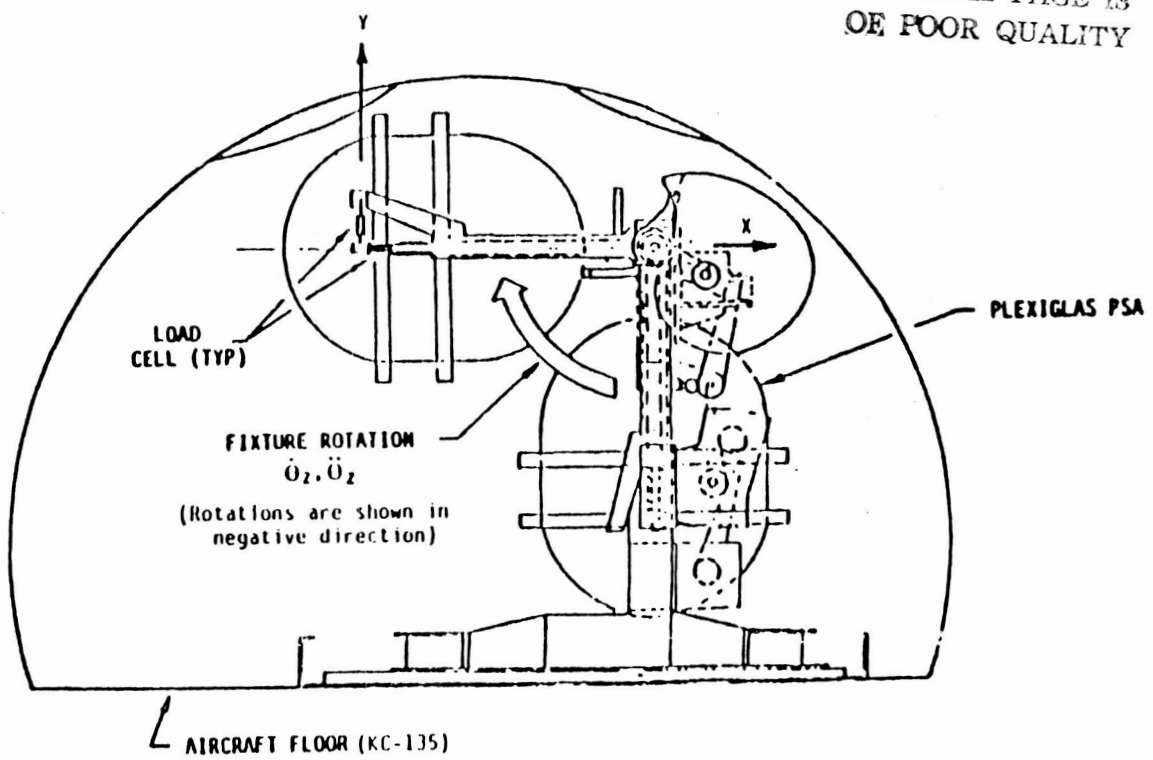
- **COMPARE EXPERIMENTAL MODEL WITH COMPUTER GENERATED MODEL**
- **EXPERIMENTAL MODEL**
  - BUILD MODEL TANK WITH BAFFLES
  - TEST APPARATUS WITH SINGLE AXIS OF ROTATION FOR SIMPLICITY
  - TEST APPARATUS IN LOW GRAVITY ENVIRONMENT USING KC-135
  - MEASURE FORCES AND MOMENTS
- **COMPUTER MODEL**
  - USE KC-135 TANK VELOCITY AND ACCELERATION DATA AS INPUT TO MODEL
  - MODEL OUTPUT (PREDICTED FORCES AND MOMENTS) COMPARED WITH EXPERIMENTAL DATA

PROPELLANT STORAGE ASSEMBLY

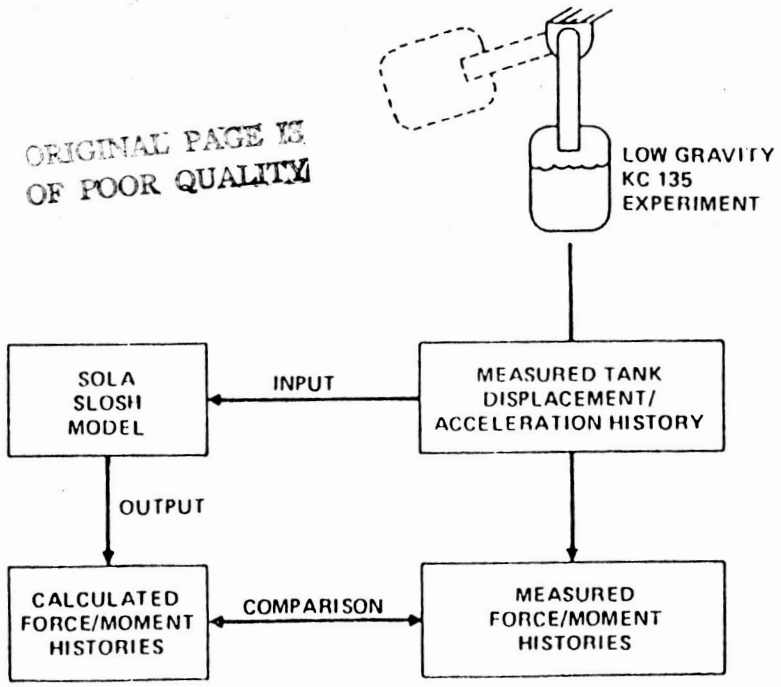


LOW-G ROTATIONAL TESTING

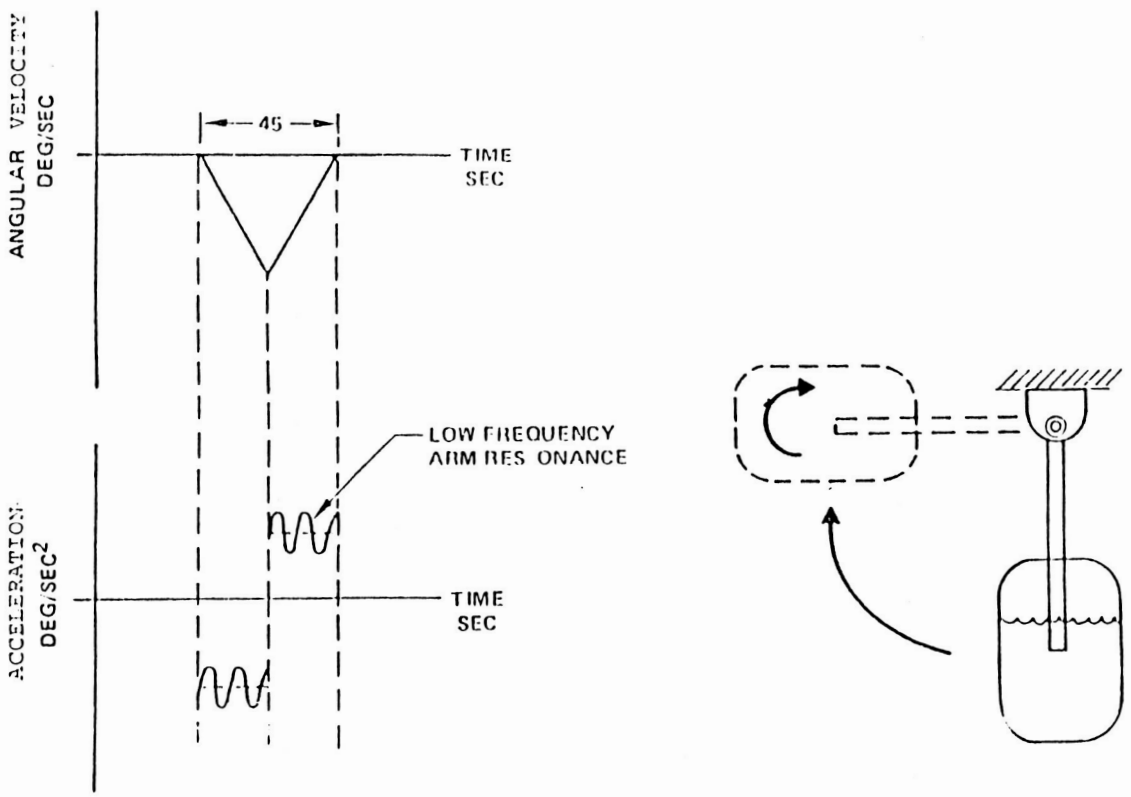
(VIEW LOOKING AFT IN AIRCRAFT)

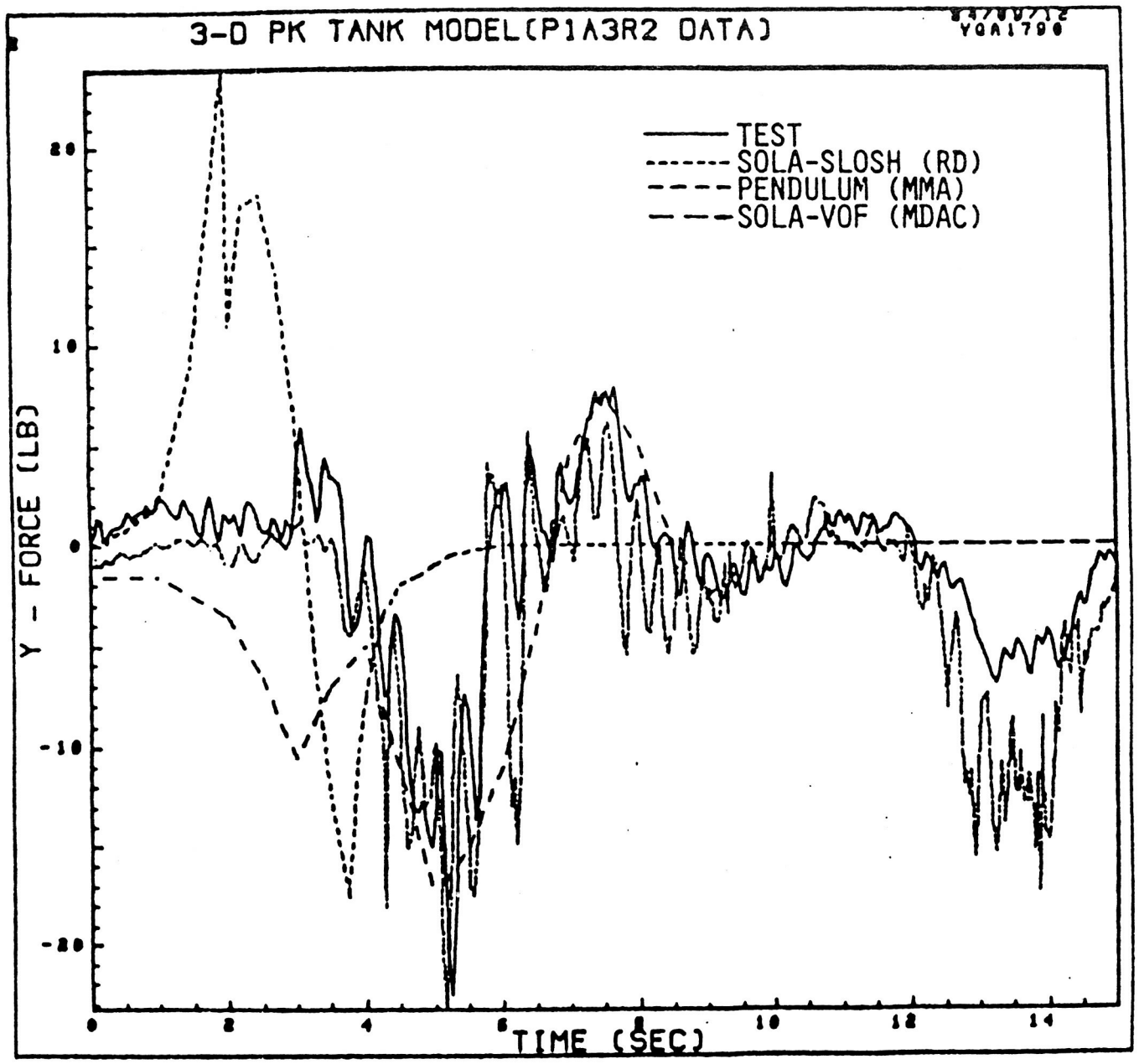


KC 135 EXPERIMENTAL MODEL COMPUTATIONAL MODEL COMPARISON



ROTATIONAL MOTION IN EXPERIMENT




3-D PK TANK MODEL(P1A3R2 DATA)
VQA1796
TEST
SOLA-SLOSH (RD)
PENDULUM (MMA)
SOLA-VOF (MDAC)
Y - FORCE (LB)
20
10
0
-10
-20
0
2
4
6
8
10
12
14
TIME (SEC)

MODEL COMPUTATION OBSERVATIONS

- **COARSE GRID CASE RESULTS AGREED WELL WITH SAME CASE USING A FINE GRID**
  - COARSE GRID CASE COST LESS THAN ONE PERCENT OF COST TO RUN FINE GRID
  - PRIMARY MOTION OF LIQUID DUE TO FLUCTUATING INERTIAL AND BODY FORCES
  - VISCOUS DRAG UNIMPORTANT IN THIS ANALYSIS
- **MODEL RESULTS ACCURATE ENOUGH TO PINPOINT FAULTY TRANSDUCERS - SUBSEQUENTLY CONFIRMED BY EXAMINING TRANSDUCERS**

SLOSH-3D RUN SPECIFICS OF KC-135

SERIES A4 RUN 3 TEST SIMULATION

- COARSE MESH (3 x 6 x 8)
- LATERAL SYMMETRY
- COSTS $75 AT PRIORITY 3
- FINER MESH (5 x 10 x 20) BY FSI YIELDS SIMILAR RESULTS

MODEL COMPUTATION RESULTS

- **SOME DISCREPANCY BETWEEN MODEL RESULTS AND DATA**
  - BELIEVED TO BE DUE TO INACCURATE DISPLACEMENT AND ACCELERATION INPUTS
  - THESE INPUTS MEASURED AT CENTER OF ROTATION RATHER THAN ON TANK ITSELF - "ARM FLEXIBLE"
  - AS FREE SURFACE MOVES THROUGH CELL GET COMPUTATIONAL SINGULARITY EXAGGERATED IN COARSE MESH - SORT OF A COMPUTATIONAL "WATER HAMMER"
    - MOMENT AND FORCE SPIKES (COMPRESSIBILITY IN SOLUTION HELPS TO DEPRESS MAGNITUDE)

KC-135 PHASE I TEST

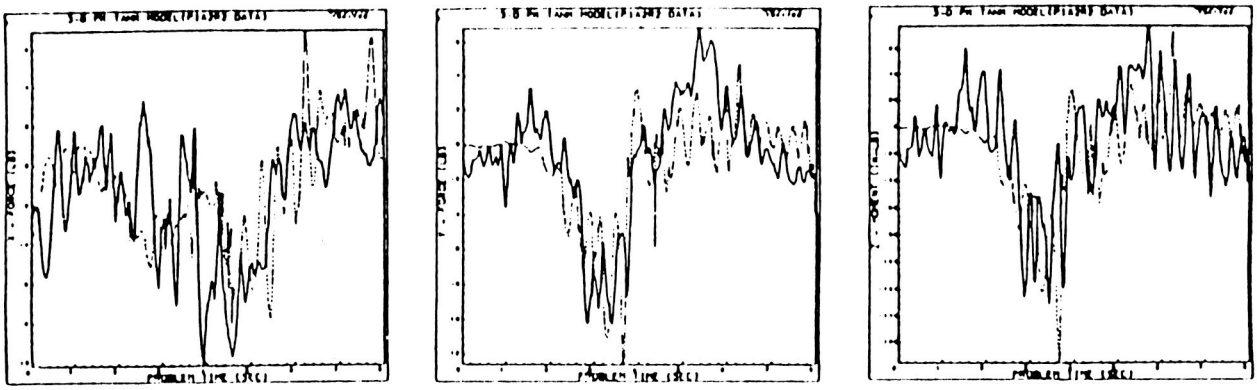
SERIES A4 RUN 3

ANALYSIS

. EXCELLENT LOW FREQUENCY CORRELATION ($\leq$ 0.5 Hz)

. POOR CORRELATION NEAR TEST STRUCTURE RESONANCE ($\sim$ 3 Hz)

. REASONABLE HIGHER FREQUENCY CORRELATION



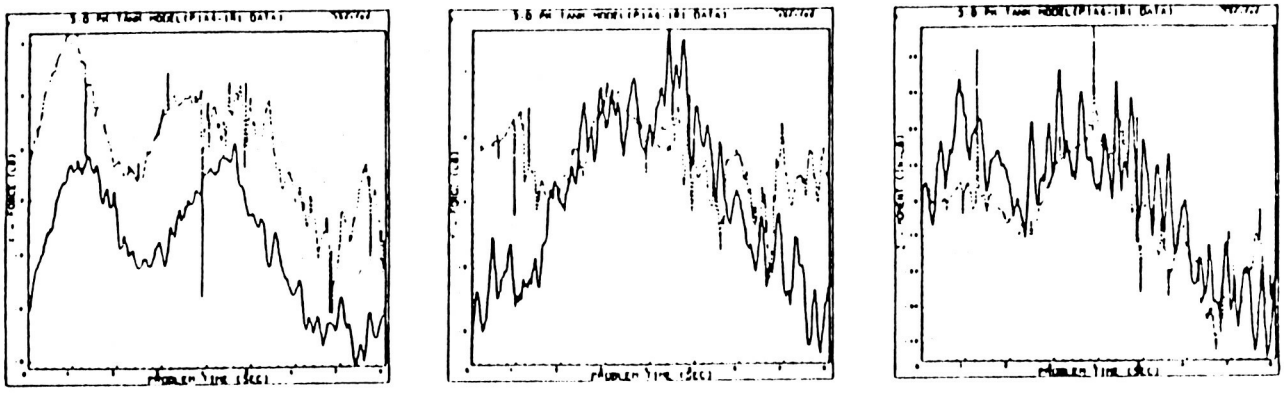
MODEL/EXPERIMENT COMPARISON

PHASE I. SERIES A2. RUN 2

30% FILL. NO BAFFLES

———— EXPERIMENT

--------- MODEL



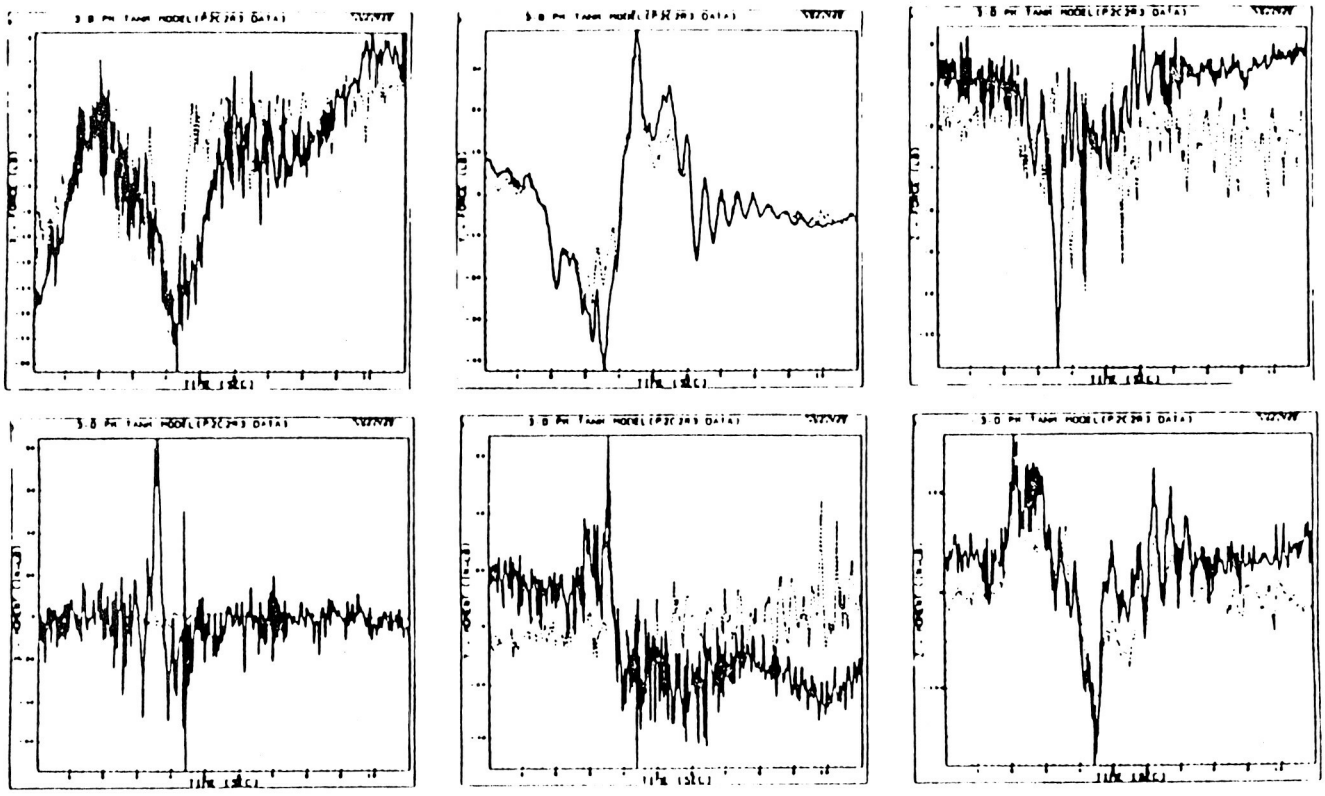
MODEL/EXPERIMENT COMPARISON

PHASE I. SERIES A4-1. RUN 1

30% FILL. RING/CONE BAFFLES

———— EXPERIMENT

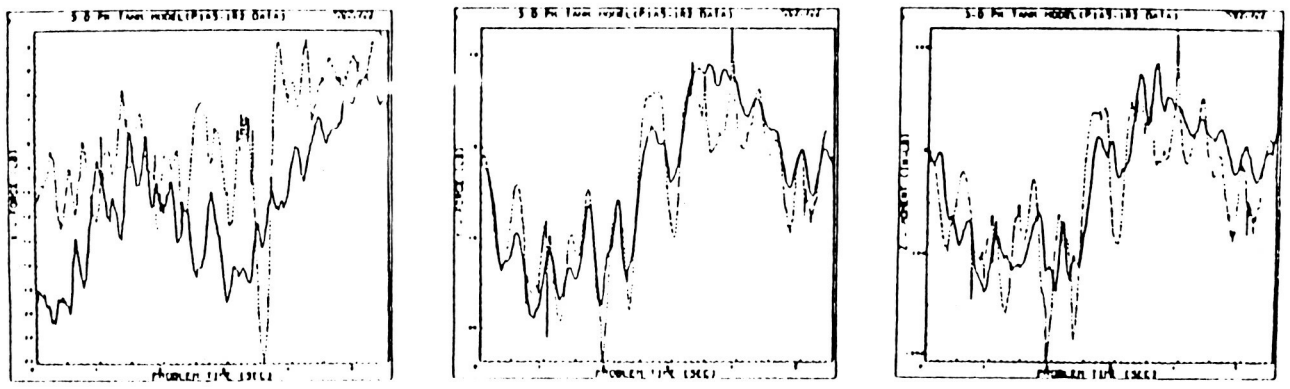
--------- MODEL



MODEL/EXPERIMENT COMPARISON
PHASE II, SERIES C2, RUN 3
40% FILL, RING/CONE BAFFLES

———— EXPERIMENT

--------- MODEL



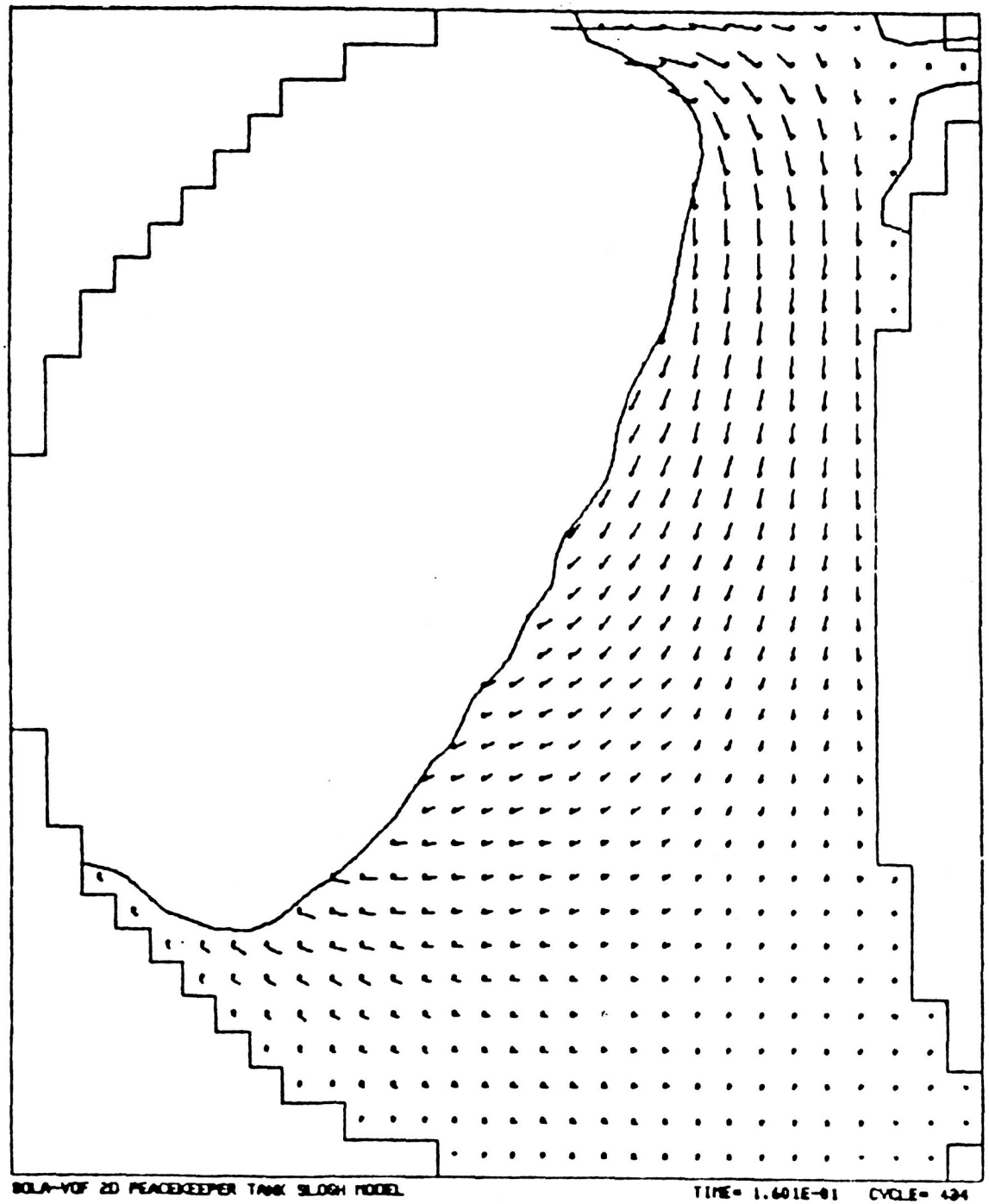
MODEL/EXPERIMENT COMPARISON

PHASE I, SERIES A5-1, RUN 2

60% FILL, RING/CONE BAFFLES

———— EXPERIMENT

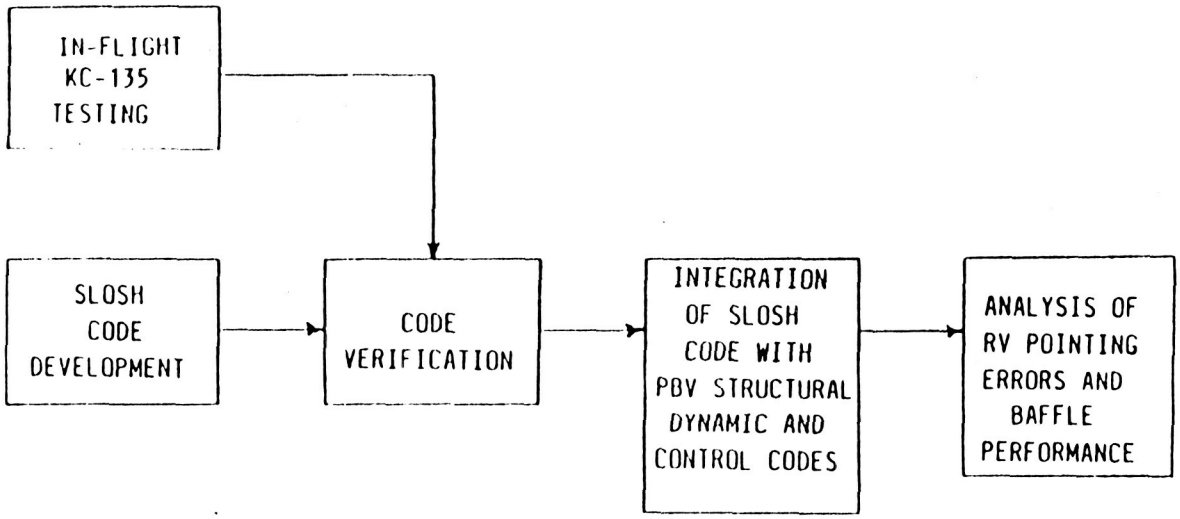
--------- MODEL



SLOSH
SIMULATION
(SOLA-VOF)

PROPELLANT RESIDUAL MOTION ANALYSIS

FLOW CHART



- SLOSH MODEL INTEGRATED WITH AUTONETICS CONTROL MODEL TO EVALUATE BAFFLE PERFORMANCE IN A WORST CASE DUTY CYCLE

- AUTONETICS REPORT OF 15 JUNE 1984, CONCLUDED THAT BAFFLES WERE NOT NECESSARY