PAPER Nr.: 105

ROTORCRAFT ANALYSIS IMPROVEMENTS ARE NEEDED TO REDUCE DEVELOPMENT RISK

by

CHAS CRAWFORD

TO BE PRINTED IN JAN 90 AHS JOURNAL

FIFTEENTH EUROPEAN ROTORCRAFT FORUM

SEPTEMBER 12 - 15, 1989 AMSTERDAM

ROTORCRAFT ANALYTICAL IMPROVEMENTS ARE NEEDED

AMERICAN HELICOPTER SOCIETY

TO REDUCE DEVELOPMENTAL RISK

9TH NIKOLSKY LECTURE

15th European Rotorcraft Forum

INTRODUCTION

- *the need is --*

  TO DESIGN VERTICAL LIFT AIRCRAFT THAT "fly off the drawing board" WITHOUT SIGNIFICANT CHANGES BEFORE QUALIFICATION / PRODUCTION

- *the problem is --*

  SHORTFALLS IN REALISM AND MATURITY OF ANALYTICAL TOOLS AVAILABLE TO DESIGN TEAMS

NIKOLSKY '89

DEVELOPMENT, ACQUISITION, OPERATIONAL PHASES

Under constant scrutiny -- high cost

- *ACQUISITION & OPERATING COST REDUCTIONS BEST ADDRESSED BY DESIGN TEAMS / USERS*
- *EFFICIENCIES IN DEVELOPMENT PROCESS IS ALSO A TECHNOLOGY ISSUE*
- *MANY MGMT IMPROVEMENTS SUGGESTED,*

  but but **but**

- *BETTER UNDERSTANDING OF ROTORCRAFT ANAL MATURITY, DEVEL RISK, PREL DESIGN PROCESS NEEDED AT BUDGET APPROV LEVELS IN BOTH EXECUTIVE & LEGISLATIVE BRANCHES*

NIKOLSKY '89

MANAGEMENT IDEAS

initiatives like

- *PERFORMANCE ORIENTED SPECS*
- *DESIGN FREEDOM*
- *SPECIFICATION TAILORING*
- *OVERLAPPING DEVELOPMENT & PRODUCTION*
- *PROGRAM FINANCIAL STABILITY*
- *CONCURRENT ENGINEERING*

will not compensate for

- *WEAK ANALYTICAL METHODOLOGY*

NIKOLSKY '89

ORDER OF PRESENTATION

- *MULTI-DISCIPLINED TECHNOLOGY COMPLEXITIES OF ROTORCRAFT DESIGN*
- *HIGHER RISK ELEMENTS OF AIR VEHICLE DESIGN (vibration & loads, aero perf, weight ests)*
- *RECORD OF DESIGN CHANGES AFTER FLIGHT*
- *IMPROVEMENTS IN WORK*
- *CONCLUSION*

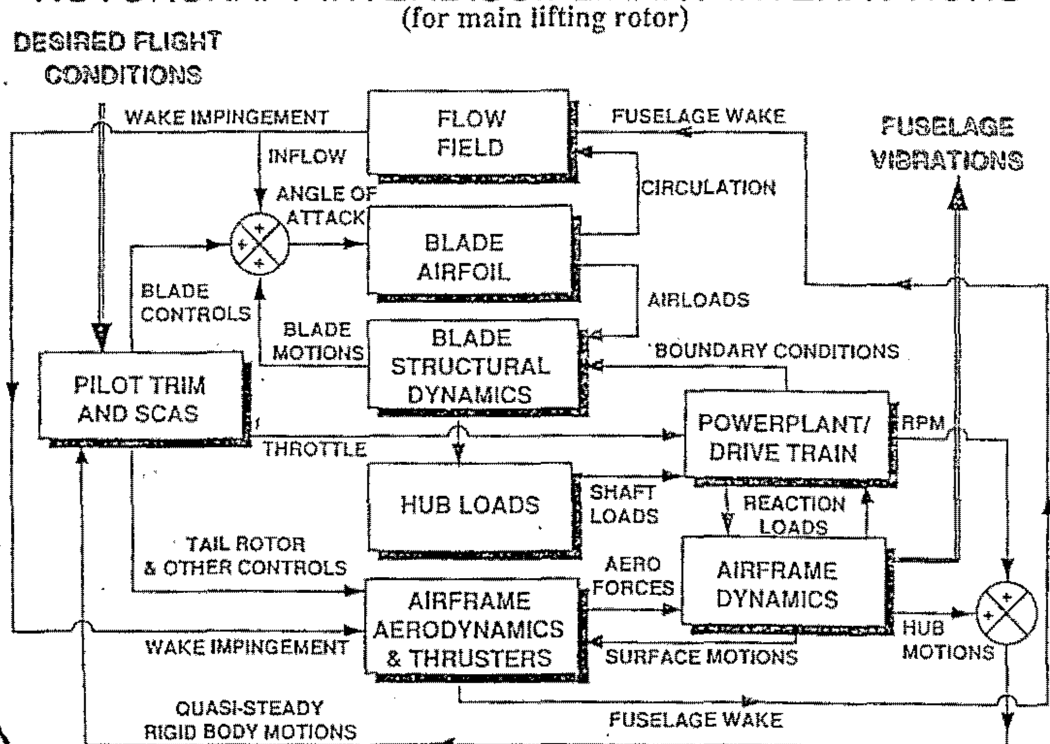
NIKOLSKY '89

INTERDISCIPLINARY CAPABILITY OF ROTORCRAFT

- *OVERVIEW*
- *ROTOR ANALYSIS*
- *AIRFRAME DYNAMICS*
- *AIRFRAME / ROTOR AERODYNAMIC INTERACTION*
- *POWERPLANT / DRIVE TRAIN DYNAMICS*
- *PILOT / SCAS INPUTS*

NIKOLSKY '89

ROTORCRAFT INTERDISCIPLINARY INTERACTIONS
(for main lifting rotor)



NIKOLSKY '89

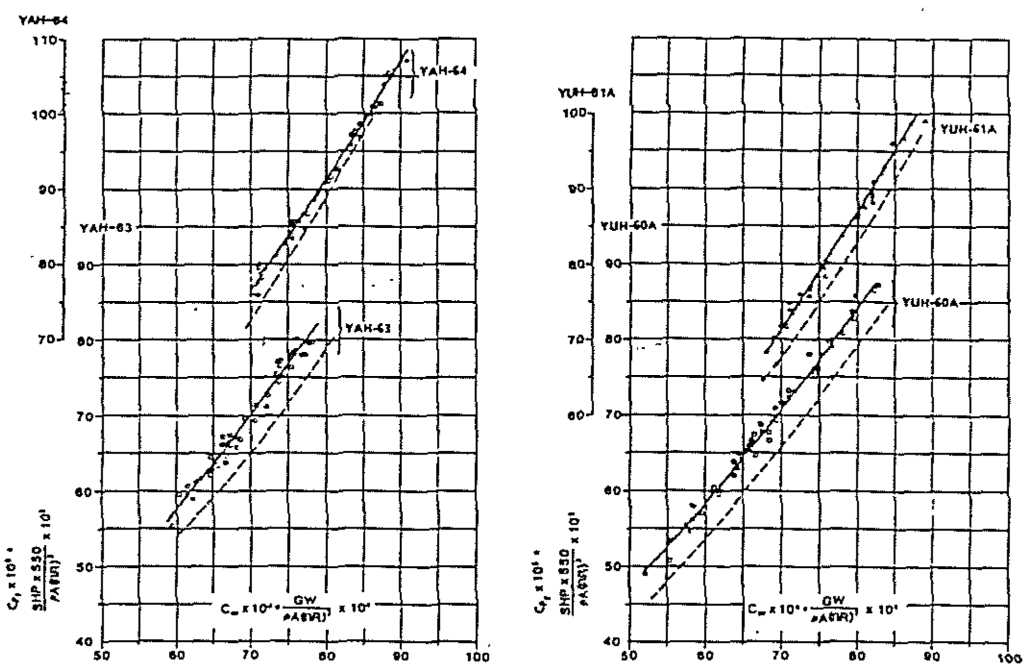
AERODYNAMIC PERFORMANCE

- *HOVER PERFORMANCE*
  (usually overstated by 4 to 9%)
- *VERTICAL CLIMB PERFORMANCE*
  (momentum theory is pessimistic)
- *FORWARD FLIGHT ESTIMATES*
  -- BLADE FLAPPING AND ROTOR THRUST
  -- ADVANCING & RETREATING STALL CHAR
  -- ROTOR PROFILE AND INDUCED DRAG

  (dynamic stall modeling is questionable ,
  profile estimates adequate,
  induced drag requires complex wake analysis)

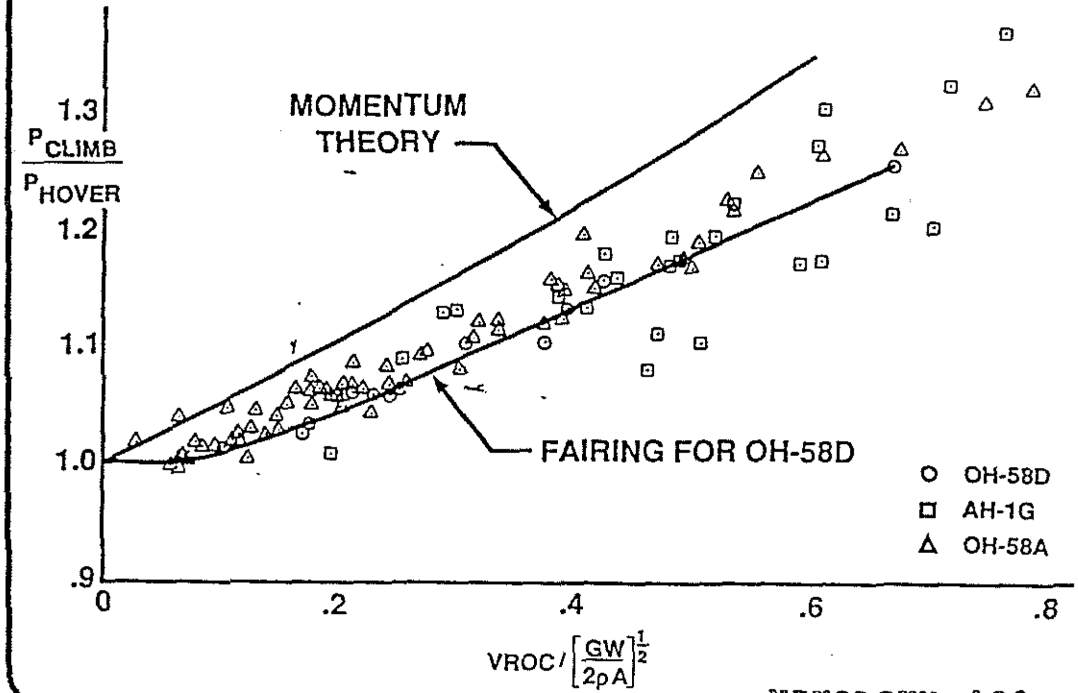
NIKOLSKY '89

UTTAS/AAH HOVER OGE PERFORMANCE
(predicted vs. actual)



NIKOLSKY '89

MOMENTUM THEORY OVERPREDICTS POWER REQUIRED FOR VERTICAL CLIMB



NIKOLSKY '89

AERO EST vs ACTUAL CR SPEED

Army Reqt = 145 KTAS @ 4K / 95°F
with Max Cont Power

	UH-60	UH-61	AH-63	AH-64
MISSION GW (lbs)	16850	16410	16050	14240
EST. CR SPEED* (ktas)	157	147	143	145
FLT TEST RESULT (ktas)	138	134	122	141

* ESTIMATED SPEED ADJUSTED TO "TEST" MISSION GR. WT.

NIKOLSKY '89

1987 NASA CONFERENCE RESULTS (aerodynamics)

- *CFD CODES MAKE IT POSSIBLE TO PREDICT SOME ASPECTS OF ROTOR PERFORMANCE*
- *SIGNIFICANT FLOW PROBLEMS STILL REMAIN*
  - *3-D STALL*
  - *INTERACTIONAL AERODYNAMICS (BLADE-VORTEX, M/R-T/R, ROTOR-FUS)*
- *POTENTIAL PAYOFF TO OVERALL ANALYSIS CAPABILITY REMAINS HIGH, USING COMBO OF COMPUTATIONAL, EXPERIMENTAL, AND OPERATIONAL CAPABILITIES*

NIKOLSKY '89

VIBRATION PREDICTION

- *DYNAMIC FEM IS STARTING TO MATURE, BUT IS TOO TIME CONSUMING TO IMPACT DESIGN*
- *INABILITY TO ACCURATELY PREDICT LOADS MAKES VIBRATION ANALYSIS INACCURATE*
- *VIBRATION LEVELS DECREASING OVER THE YEARS DUE TO COSTLY FLT MODS & WEIGHT-PENALIZING VIB REDUCTION DEVICES - NOT BETTER VIB PREDICTIONS*
- *GIVEN THE IMPORTANCE OF VIBRATIONS, WE MUST DEVELOP OUR ANALYTICAL TOOLS*

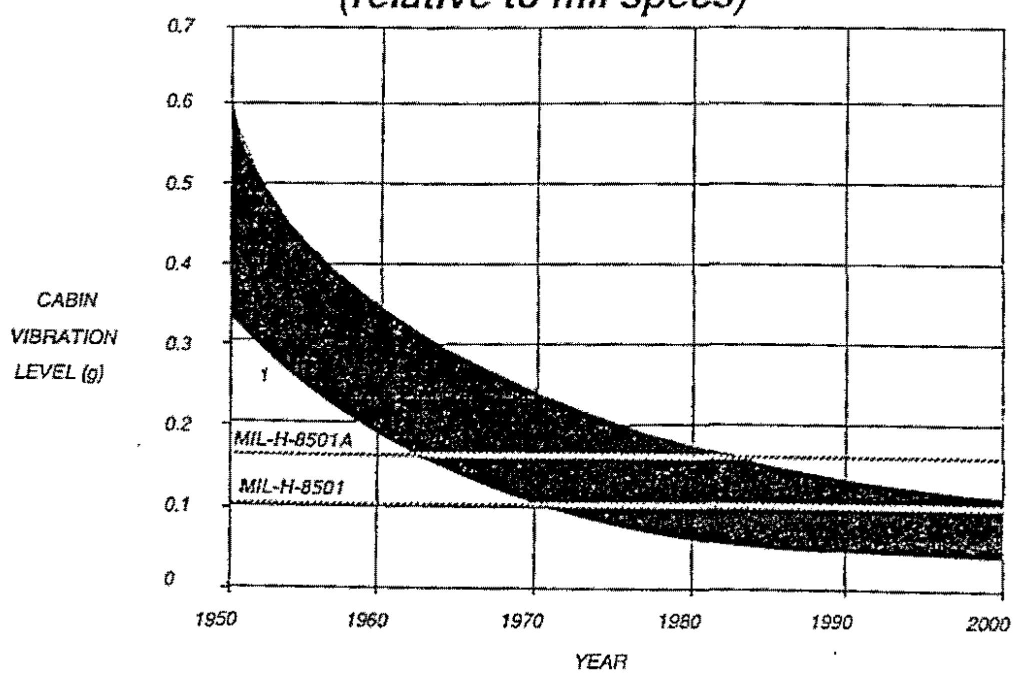
NIKOLSKY '89

1987 NASA CONFERENCE RESULTS (vibrations)

- FIXING VIBRATION PROBLEMS AFTER FIRST FLIGHT IS COSTLY
- REQUIREMENT FOR LOW VIBRATIONS IS NOW A CRITICAL DESIGN CONSIDERATION, WHICH CAN NO LONGER BE ADDRESSED IN AN AD HOC MANNER
- IMPORTANT ELEMENTS NEEDED FOR "JET SMOOTH" RIDE ARE EMERGING
- STILL MUCH ROOM FOR IMPROVEMENT

NIKOLSKY '89

TREND OF HELICOPTER VIBRATION (relative to mil specs)



NIKOLSKY '89

ROTOR LOADS PREDICTION

- ADVANCED "INTERDISCIPLINARY" CODES, SUCH AS C81 & CAMRAD, ARE SHOWING SOME CORRELATION
- COUPLING OF BLADE MODES, AIRFRAME / ROTOR AERO INTERFERENCE, HUB BOUNDARY CONDITIONS, & OTHER FACTORS NOT INCLUDED IN ANALYSIS ARE IMPORTANT
- NEED AN IMPROVEMENT IN THE BASIC TECHNOLOGY - NOT JUST INTEGRATION OF TODAY'S TECHNOLOGY

NIKOLSKY '89

1987 NASA CONFERENCE RESULTS (rotor loads)

- PREDICTIVE CAPABILITY AVAILABLE IS MARGINAL FOR OSCILLATORY LOADS UNSATISFACTORY FOR VIBRATORY LOADS
- PRESSING NEED FOR GOVT ROTOR LOADS PREDICTIVE CAPABILITY
- LACK OF QUALITY DATA TO CORRELATE ANALYSIS TOOLS
- SUBSTANTIAL BENEFITS POSSIBLE, BUT NEED ADDITIONAL THEORETICAL WORK TO UNDERSTAND MECHANISMS OF VIBRATION

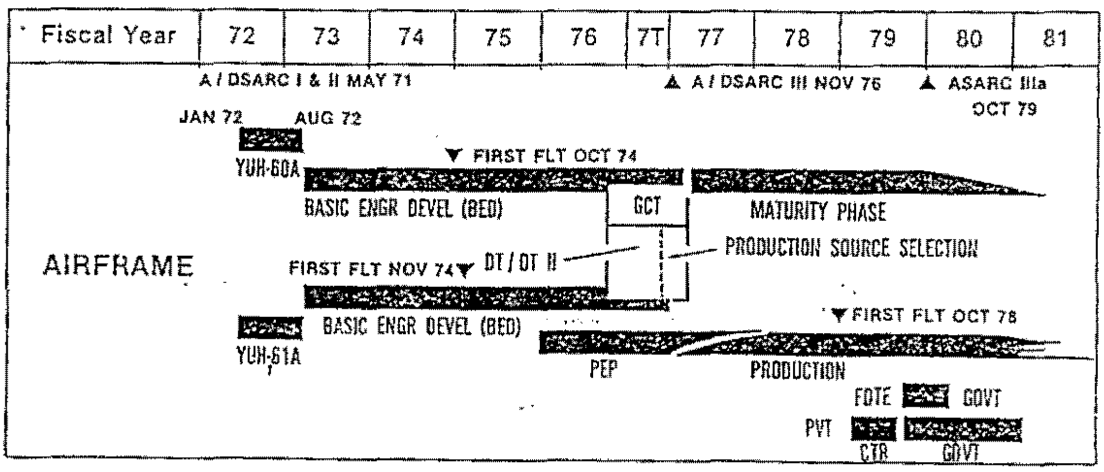
NIKOLSKY '89

MAJOR AIR VEHICLE DESIGN CHANGES IN FLT TEST

- REVIEW PROGRAM SCOPE
- ESSENTIAL CONFIG CHANGES
- WEIGHT REALISM HISTORY

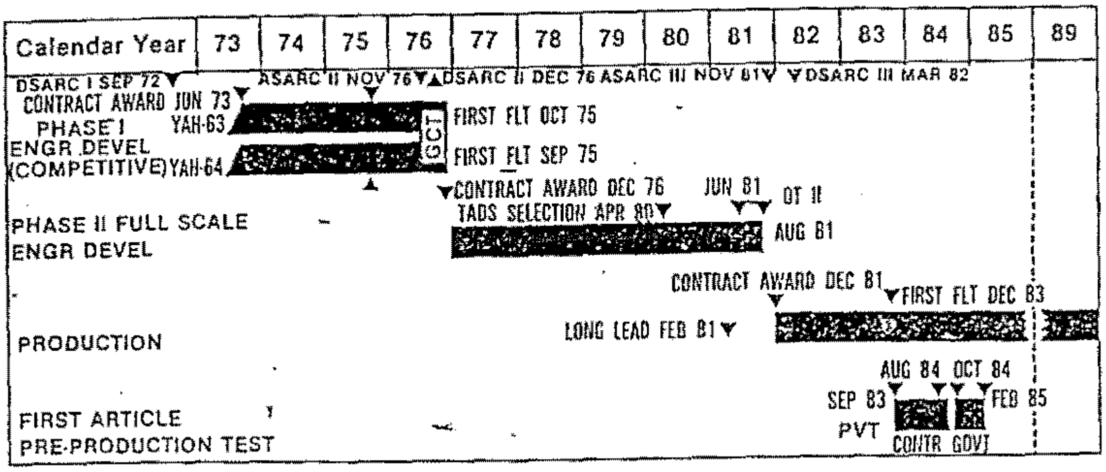
NIKOLSKY '89

UTTAS PROGRAM STRUCTURE



A / DSARC .. ARMY / DEFENSE SYSTEM ACQUISITION REVIEW COUNCIL
GCT .... GOVERNMENT COMPETITIVE TEST
PEP .... PRODUCIBILITY ENGINEERING & PLANNING
FDTE ...... FORCE DEVEL TEST & EXPERIMENTATION
PVT .... PRODUCTION VALIDATION TESTS

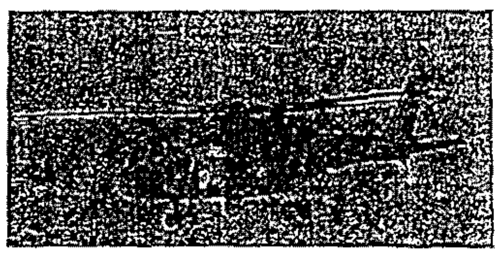
AAH PROGRAM STRUCTURE



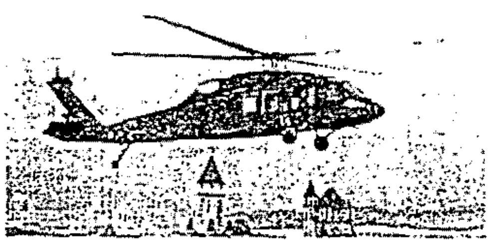
A / DSARC .. ARMY / DEFENSE SYSTEM ACQUISITION REVIEW COUNCIL
GCT .... GOVERNMENT COMPETITIVE TEST
OT .... OPERATIONAL TESTING
PVT .... PRODUCTION VALIDATION TESTS
TADS ...... TARGET ACQUISITION & DESIGNATION SYSTEM

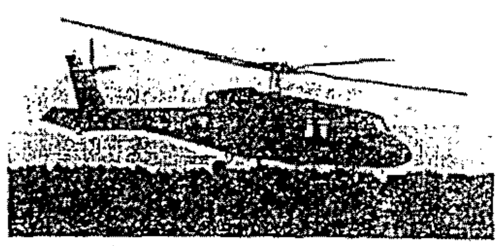
UTTAS RAISED ROTORS

YUH-60 | YUH-61



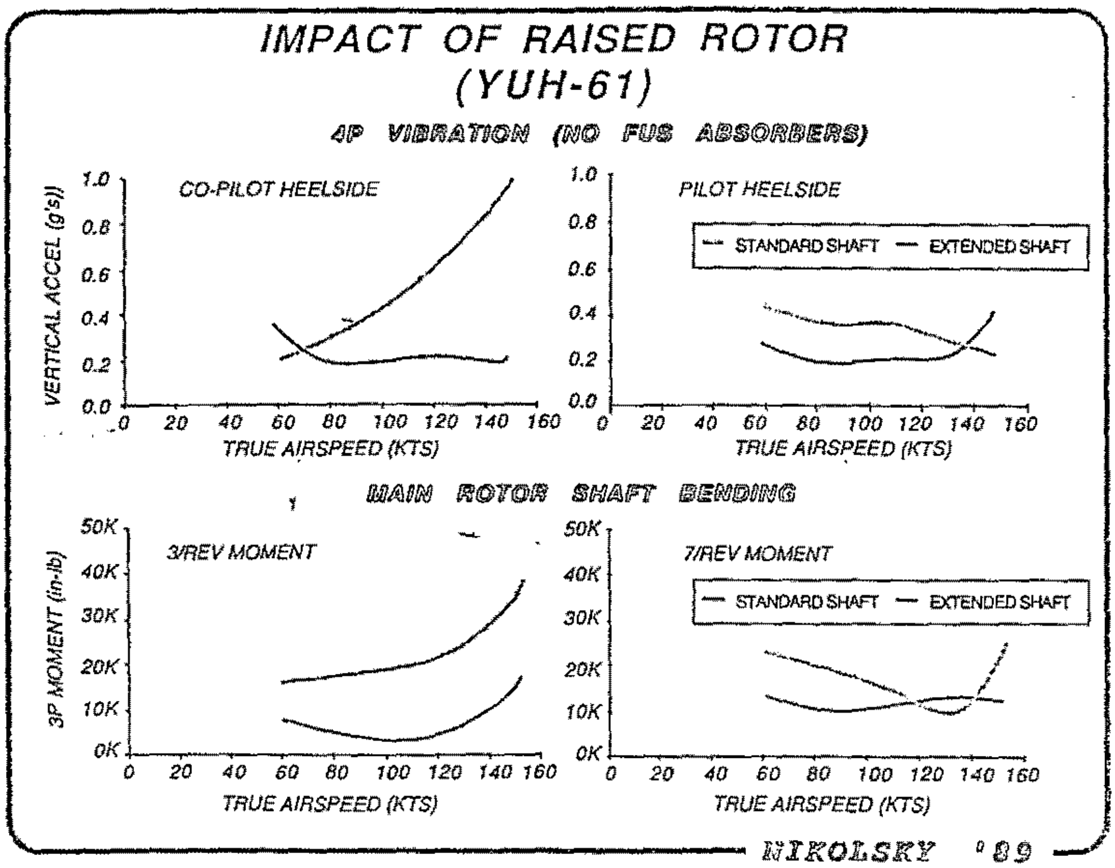
ORIGINAL ROTOR / EMPENNAGE | *COMPETITION TEST CONFIG*

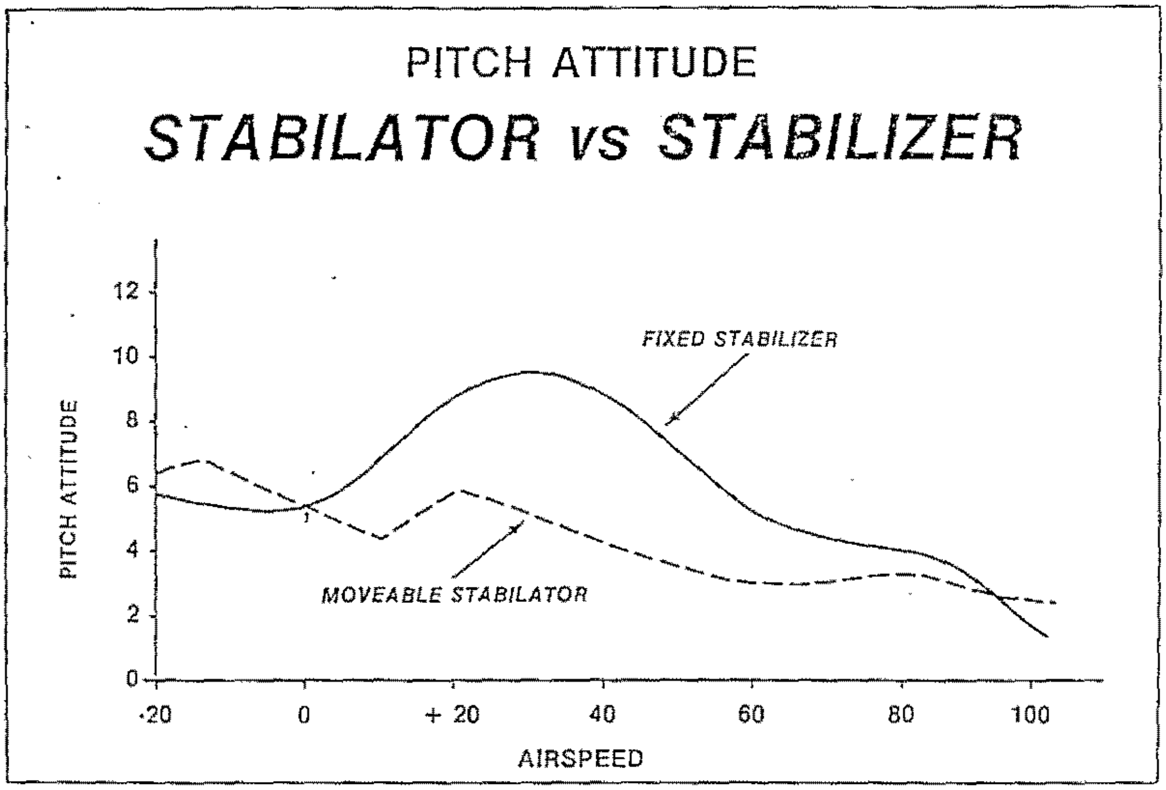




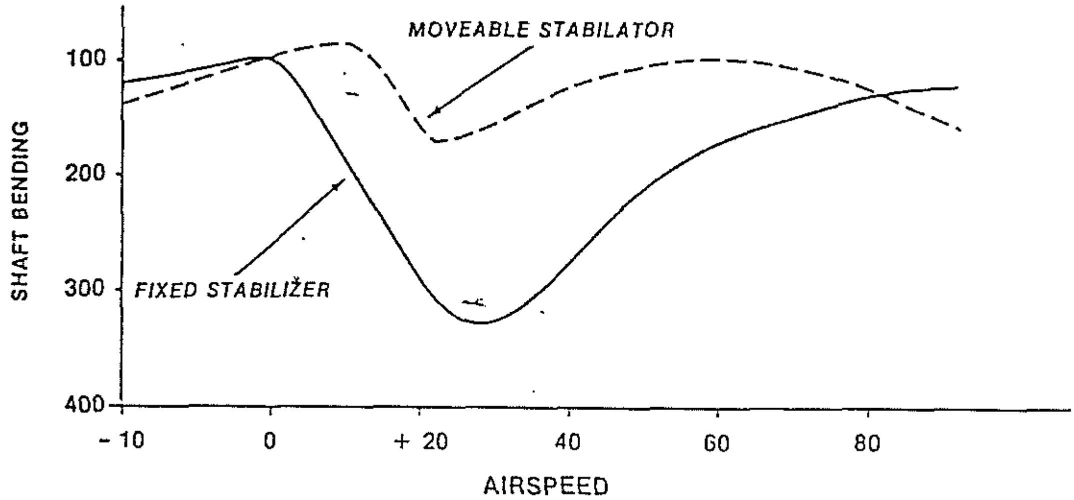
FINAL ROTOR / EMPENNAGE | *PROPOSED FOR PRODUCTION*

NIKOLSKY '89


IMPACT OF RAISED ROTOR
(YUH-61)
4P VIBRATION (NO FUS ABSORBERS)
CO-PILOT HEELSIDE
PILOT HEELSIDE
STANDARD SHAFT
EXTENDED SHAFT
VERTICAL ACCEL (g's))
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
100
120
140
160
TRUE AIRSPEED (KTS)
MAIN ROTOR SHAFT BENDING
3/REV MOMENT
7/REV MOMENT
3P MOMENT (in-lb)
50K
40K
30K
20K
10K
0K
NIKOLSKY '89


PITCH ATTITUDE
STABILATOR vs STABILIZER
FIXED STABILIZER
MOVEABLE STABILATOR
PITCH ATTITUDE
12
10
8
6
4
2
0
-20
0
+ 20
40
60
80
100
AIRSPEED

MAIN ROTOR SHAFT BENDING
STABILATOR vs STABILIZER



YUH-60A REQUIRED DESIGN CHANGES

TOPIC	*FLT TEST PROBLEM*	*DESIGN CHANGE*
• BASIC AIRFOIL	• MAX LOAD FACTOR LOW	• ADDED DROOP SNOOT
• MAIN ROTOR BLADE	• HOVER CAPABILITY LOW	• TIP CAP EXTENDED 4 INS/BLADE
• ROTOR HEIGHT	• HIGH VIBRATION HIGH ROTOR BLADE LOADS	• ROTOR MAST INCREASED 15 INS
• STABILATOR CONFIG	• AIRCRAFT ATTITUDES IN LOW SPEED FLT REGIMES • HIGH SHAFT BENDING	• LOW FIXED STABILIZER RAISED • MADE MOVABLE OVER A 43 DEG RANGE THRU AUTO CONTROLS
• VERTICAL FIN AREA	• LARGE TRIM CHANGE UNSTABLE SIDEWARD FLT	• REDUCED FIN AREA WITH CUT-OUT
• TAIL ROTOR MOUNT & CONTROL	• HIGH FLT LOADS	• ROTOR SHAFT, SUPPORT STRUCT, & CONTROLS REDESIGNED FOR INCREASED STRENGTH
• LANDING GEAR SPONSON	• HIGH DRAG	• CHANGED INCIDENCE ANGLE TO ALIGN WITH FUS FLOW
• TAIL ROTOR GEARBOX	• UNDETECTED OVERTEMP	• REPLACED GREASE LUB WITH OIL
• CONTROL SYSTEM AUTHORITY	• POOR CONTROL HARMONY	• LAT SENSITIVITY INCREASED YAW/ROLL MECHANISM INCORPOR
• MAIN ROTOR SERVOS	• HIGH FLT LOADS	• REDESIGNED FOR INC STRENGTH
• MAIN ROTOR DAMPERS	• HIT DAMPER STOPS IN HIGH SPEED AUTOROTATION	• MOVED INBOARD DAMPER OUTBOARD BY 3.5 INS
• MAIN TIRES	• MECHANICAL GROUND INSTABILITY	• INCREASED SIZE & PRESSURE TO INCREASE STABILITY MARGINS
• AIRSPEED SYSTEM	• EXCESSIVE ERROR	• FLEW OVER 100 FLTS TO OPTIMIZE
• AFT NACELLE CONFIG	• HIGH TAIL VIBRATION & BUFFET	• REDESIGNED TO IMPROVE AIRFLOW PATH
• STABILITY AUG SYS	• VARIABLE FLT CONTROL SYS CHARS W/ EXTREME TEMPS	• CHANGED FROM FLUIDIC TO ELECTRICAL/MECHANICAL

NIKOLSKY '89

YUH-61 REQUIRED DESIGN CHANGES

TOPIC	FLT TEST PROBLEM	DESIGN CHANGE
• ROTOR AEROELASTIC STAB	• EVAL WITH/WITHOUT DAMPERS (INITIALLY REQUIRED BY ARMY)	• LAG DAMPERS REMOVED
• TAIL ROTOR SIZE	• REDUCED SIDEWARD FLT MANEUVER CAPABILITY	• INCREASED DIA FROM PROPOSAL, FURTHER INCREASE FOR PROD
• ROTOR WAKE INTERFERENCE ON TAIL ROTOR	• YAW "KICKS" IN SOME FLT COND	• ADDED BEANIE LARGER FAIRING FOR PROD
• LATERAL CONTROL TRAVEL	• RAN OUT OF CONTROL DURING LOW SPEED MANEUVERING	• DOUBLED LAT SWASHPLATE TRAVEL
• FLT CONTROLS RATE LIMITED	• TOO SLOW FOR MANEUVERING	• DOUBLED CONTROL ACTUATOR MAXIMUM RATE
• VERTICAL FIN SIZE	• EXCESSIVE T/R BLOCKAGE IN SIDEWARD FLT	• REDUCED FIN CHORD
• VIBRATION ABSORBERS	• EXCESSIVE VIBRATION	• ADDITIONAL FUS ABSORBERS EXTENSIVE TESTING OF ABSORBER INSTALLATIONS
• PITOT STATIC SYSTEM	• EXCESSIVE ERROR	• MANY LOCATIONS TESTED
• HORIZONTAL TAIL SIZE	• MOVABLE TAIL ADDED COMPLEXITY • SPAN COMPROMISED AIR TRANS	• FLEW FIXED HALF SIZE TAIL PROPOSED SAME FOR PROD
• ROTOR HEIGHT	• EXCESSIVE VIBRATION	• ROTOR MAST INCREASED 24 INS FOR PROD

NIKOLSKY '89

YAH-63 REQUIRED DESIGN CHANGES
(all items only proposed for production)

TOPIC	FLT TEST PROBLEM	PROPOSED DESIGN CHANGE
• ROTOR DIAMETER	• WEIGHT INCREASE	• INCREASE DIAMETER BY 6 INS
• AIRFOIL SECTION	• ADV BLADE TUCK	• REDUCED THICKNESS OF OUTBOARD 25%
• ROTOR HEIGHT	• TAIL BOOM CLEARANCE FOR SLOPE LANDING	• INCREASE MAST BY 18 INS ADDED 1.2 DEG FWD TILT
• MAST ANGLE	• LOW CRUISE SPEED	• ADDED FAIRINGS FOR BLADE GRIP & HUB
• MISC FAIRINGS	• LOW CRUISE SPEED	• SPRING TORQUE TUBE
• BLADE FLAPPING	• INCREASE MANEUVER ENVELOPE	• INCREASED ALLOWABLE FLAPPING ELASTOMERIC FLAPPING STOP FOR ADDED CONTROL POWER ABOVE 4 DEG FLAPPING
• BLADE TIP SHAPE	• LOW CRUISE SPEED	• PLANFORM MODIFIED
• T/R BLADE SHAPE	• REDUCE TAIL POWER	• SWEPT TIP ADDED
• T/R THRUST AVAIL	• SIDEWARD FLIGHT CAPABILITY	• INCREASED COLLECTIVE PITCH AVAILABLE AND ADDED COUNTER WEIGHTS
• T/R HUB	• LOW CRUISE SPEED	• ADDED HUB FAIRING
• WING CHORD	• REDUCE FUS DOWNLOAD IN FWD FLT	• 6 INCH CHORD EXT TO CREATE A FLAP FOR ADDED LIFT
• HORIZONTAL TAIL	• POOR FLYING QUALITIES	• UPPER HORIZONTAL CHANGED TO PROVIDE A 25% CHORD CONTROLLABLE ELEVATOR
• MISC FAIRINGS	• LOW CRUISE SPEED	• ADDED WING FILLETS • MODIFIED MAIN LANDING GEAR FARIINGS • REDESIGNED ENGINE COWL TO REDUCE FRONTAL AREA & FLOW SEPARATION

NIKOLSKY '89

YAH-64A REQUIRED DESIGN CHANGES

TOPIC	FLT TEST PROBLEM	DESIGN CHANGE
• ROTOR HEIGHT	• (1) CANOPY INTERFERENCE • (2) CONTROL POWER FOR SLOPE LANDING	• EXTENDED MAST 10 INS • ADDITIONAL 6 INS EXTENSION
• DROOP STOPS	• BLADE CONTACT DURING PUSH-OVER	• OPEN STOP ONE DEG W/ FULL RAISED ROTOR
• LEAD-LAG DAMPERS	• HIGH CHORDWISE LOADS	• REDUCED DAMPER STIFFNESS 20%
• MAIN ROTOR BLADES	• UNACCEPTABLY HIGH SPEED VIB CONTROL LOADS	• SWEPT TIP TO REDUCE NOSE-DOWN PITCHING MOMENT
• EMPENNAGE CONFIG	• INADEQUATE LOW SPEED CONTROL • UNUSUAL ATTITUDE IN LOW SPEED	• FINAL CONFIG ADAPTED AUTOMATIC MOVING STABILATOR MOUNTED LOW ON TAIL BOOM • T-TAIL TRIED FOR A SIMPLE FIXED APPROACH
• TAIL ROTOR SIZE	• INADEQUATE LOW SPEED CONTROL	• INCREASED DIAMETER FROM 100 TO 110 INS
• VERTICAL FIN SIZE	• INTERFERENCE IN RIGHT SIDEWARD FLT	• REDUCED FIN AREA
• MOVABLE WING FLAPS	• EFFECT NOT APPARENT	• FIXED FOR SIMPLIFICATION/COST REDUCTION
• DIGITAL AUTOMATIC STABILIZATION EQPT	• PITCH-UP IN HIGH SPEED FLT	• DOUBLED PITCH AXIS AUTHORITY (10% TO 20%)
• XMSN SUPPORT STRUCTURE	• HIGH FLT LOADS	• REDESIGN FOR INCREASED STRENGTH & TO CHANGE NATURAL FREQUENCY
• POWER CONTROLS & ACTUATORS	• HIGH FLT LOADS	• REDESIGN FOR INCREASED STRENGTH
• TAIL BOOM TUNING	• EXCESSIVE VIBRATION IN SOME CONDITIONS	• INCORPORATED SLOT TO REDUCE NATURAL FREQUENCY
• TAIL ROTOR ACTUATORS	• SENSITIVITY TO FLT VIBS	• RELOCATED FROM UNDER COCKPIT AREA TO TAIL ROTOR VICINITY
• AREA WEAPON FIRING RATE	• EXCITED FUS VIBRATIONS	• REDUCED FROM 875 TO 625 SHOTS/MIN
• ROTOR SPEED CONTROL	• ROTOR DROOP W/ COLLECTIVE PULL	• ADDED COLLECTIVE RATE SIGNAL TO COLLECTIVE DISPLACEMENT AS ENGINE CONTROL OUTPUT

NIKOLSKY '89

UTTAS/AAH WIND TUNNEL SUMMARY

	YUH-60	YUH-61	YAH-63	YAH-64
PRE-FIRST FLIGHT				
AIRFOIL SECTIONS	130	IR&D	84	514
AIRVEHICLE	500	2278	293	432
FULL SCALE T/R	-	55	50	-
SUB-TOTAL	630	2333	425	946
POST-FIRST FLIGHT				
AIRFOIL SECTIONS	-	-	96	-
AIRVEHICLE	1470	1615	321	886
FULL SCALE T/R	160	97	24	-
SUB-TOTAL	1630	1712	451	886
PRODUCTION	455	N/A	N/A	623
GRAND TOTAL	2715	4045	876	1832

NIKOLSKY '89

WIND TUNNEL TEST OBJECTIVES

COMMON TESTS	Model Scales YUH-60	YUH-61	YAH-63	YAH-64
BASIC AIR VEHICLE DRAG	1/10	1/5	1/6	1/7
DESIGN AERO, AIRLOADS, EMPENNAGE	1/4	1/5	1/6	1/7
ISOLATED TAIL ROTOR THRUST & STABILITY	FULL	FULL	FULL	NONE

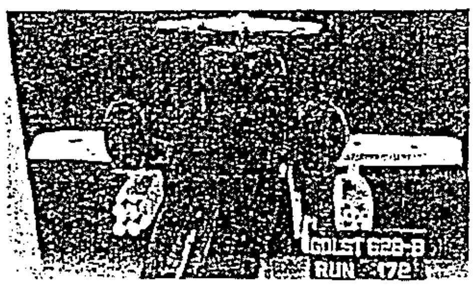
(NOTE: All contractors performed drag reduction test after 1st flight)

UNIQUE TESTS

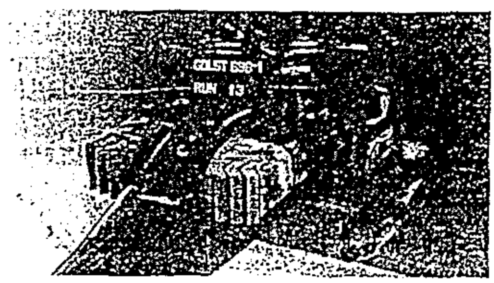
YUH-60	YUH-61	YAH-63	YAH-64
• ROTOR TIP GEOMETRY • MAIN/TAIL ROTOR INTERACTION • IMPACT OF IR SUPPRESSOR	• MODEL ROTOR FOR FORCES/ MOMENTS 10 FT DIAMETER • TAIL ROTOR AEROELASTIC STABLITY, MULTI CONFIGS • 1/5 SCALE BALLISTICALLY DAMAGED ROTOR • ENGINE EXHAUST RE-INGESTION • VIBRATION, SHUFFLE W/ RAISED ROTOR	• QUADRICYCLE LANDING GEAR • AIRFOIL TESTS (BOTH PRE & POST FLT)	• CANOPY CONFIGS • WING/FLAP & WEAPONS PYLON • EMPENNAGE ENVIRONMENT • IMPACT OF IR SUPPRESSOR

NIKOLSKY '89

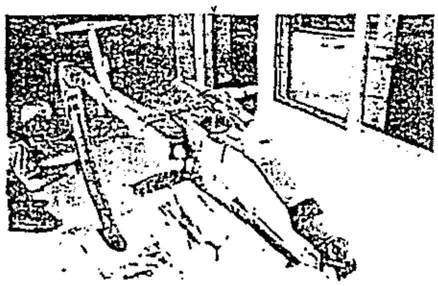
TYPICAL YAH-64 WIND TUNNEL TESTING



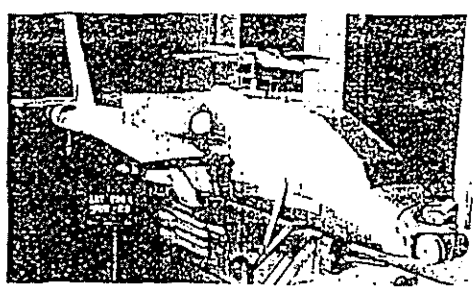
ORIGINAL ENGINE EXHAUST



IR SUPPRESSOR



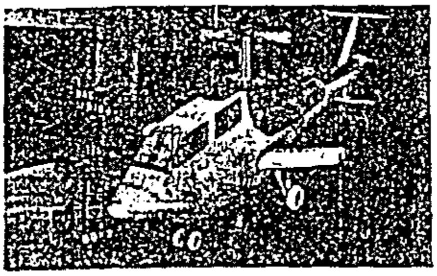
FUS WITH T TAIL



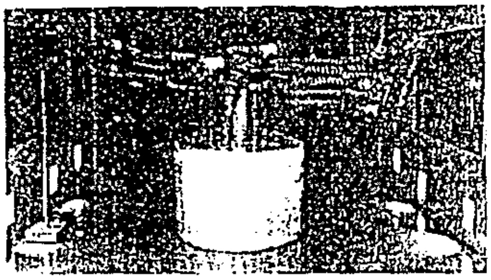
FINAL EMPENNAGE CONFIG

NIKOLSKY '89

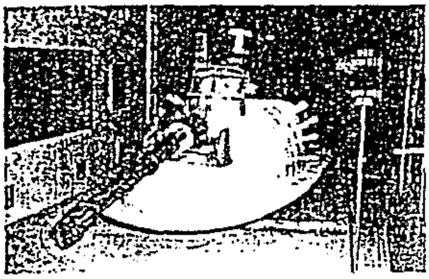
TYPICAL YAH-63 DRAG REDUCTION WIND TUNNEL TESTS



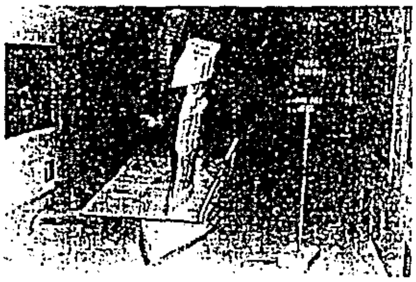
AFT NACELLE AREA



ROTOR HUB



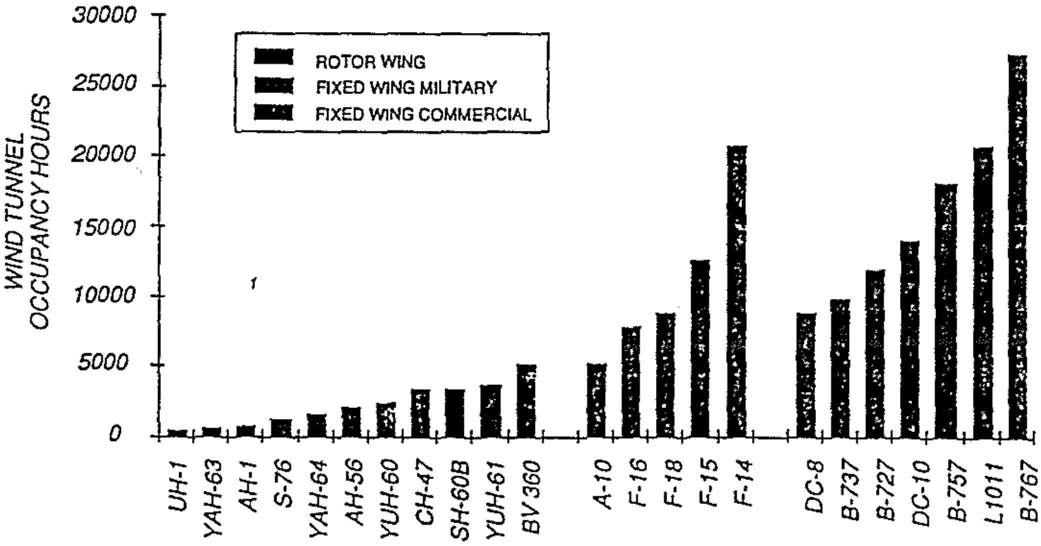
GUN FAIRINGS



LANDING GEAR FAIRINGS

NIKOLSKY '89

COMPARISON OF WIND TUNNEL TEST TIMES



NIKOLSKY '89

WEIGHT ESTIMATING REALISM

optimism driven by

- THE DESIRE TO WIN
- FAITH IN NEW TECHNOLOGY

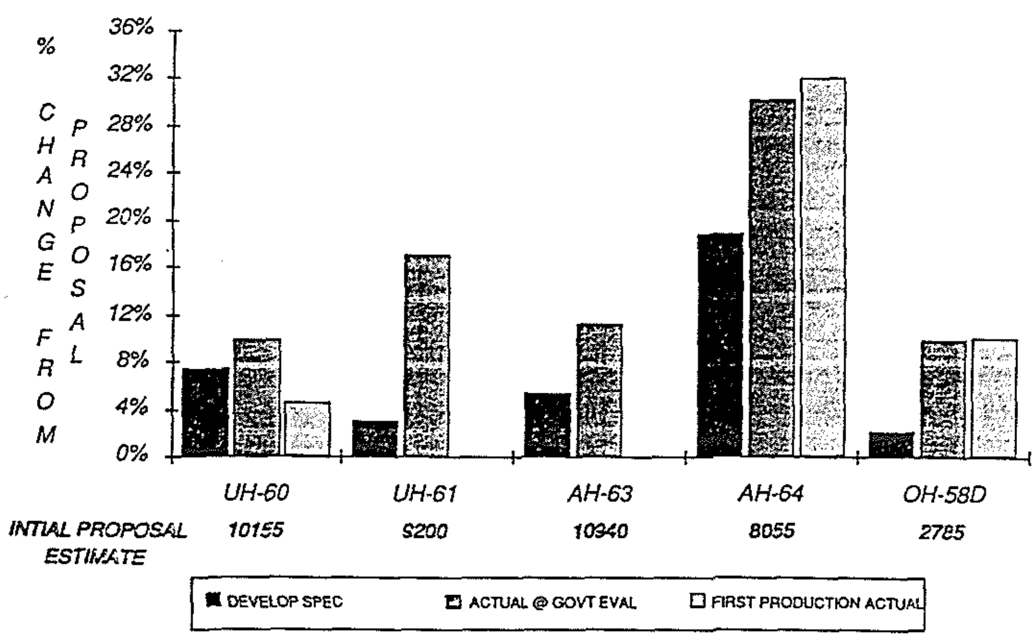
estimates complicated by

- CUSTOMER REQUIREMENTS CHANGE
- DESIGN CHANGES FOR VIABLE AIR ITEM (fixes)
- APPARENT COST IMPLICATIONS
- FLAKEY TRADE-OFF STUDIES
- UNREALISTIC SCHEDULES (no time to redesign)

NIKOLSKY '89

REALITIES OF WEIGHT PREDICTION

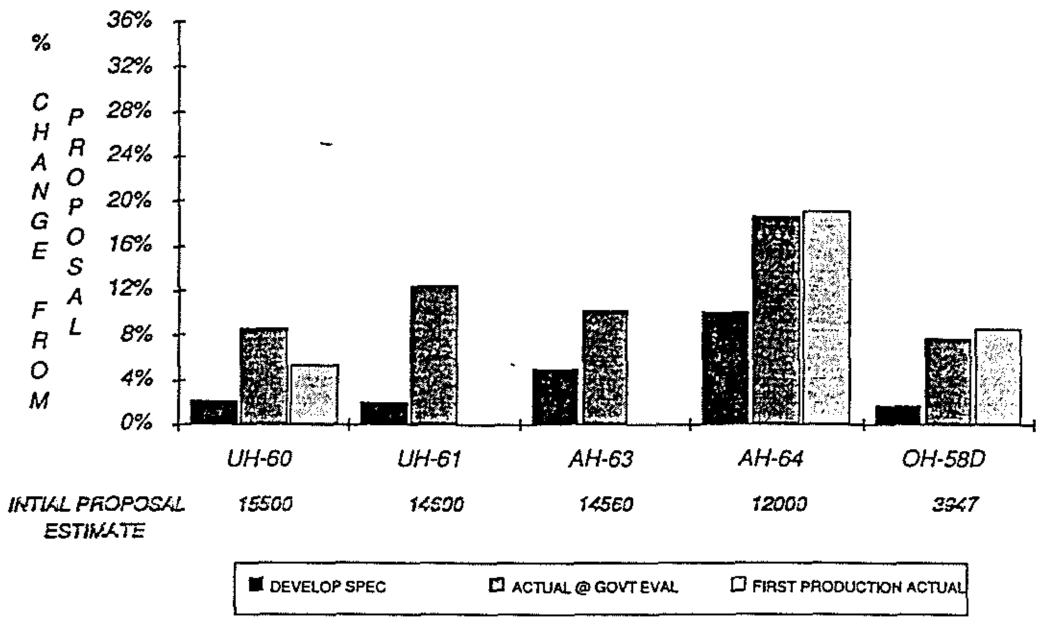
(empty weight)



NIKOLSKY '89

REALITIES OF WEIGHT PREDICTION

(primary mission weight)



NIKOLSKY '89

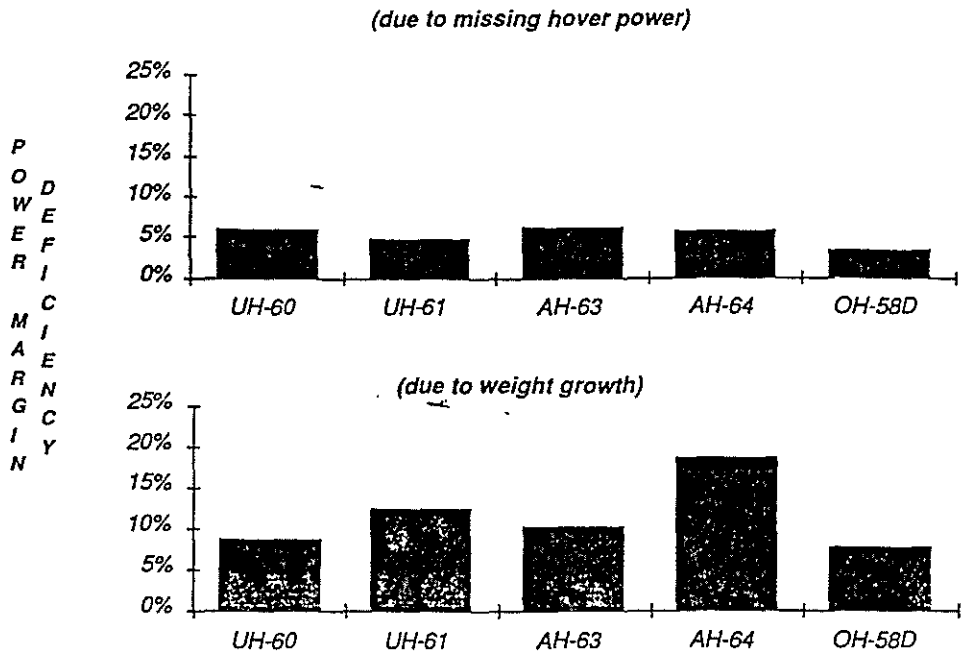
POWER MARGIN

A MOST VALUABLE INSURANCE POLICY

- ENGINE POWER GROWTH HISTORY IN SUCCESSFUL AIR ITEMS WELL KNOWN (it is not a waste)
- ROTORCRAFT TRANSMISSION GROWTH RELATIVELY SIMPLE
- SOLUTION TO MOST FLIGHT TEST PROBLEMS INVOLVES A WEIGHT INCREASE
- HIGH POWER MARGIN IN INITIAL DESIGN ALLOWS SOME WEIGHT / AERODYNAMIC ERROR

NIKOLSKY '89

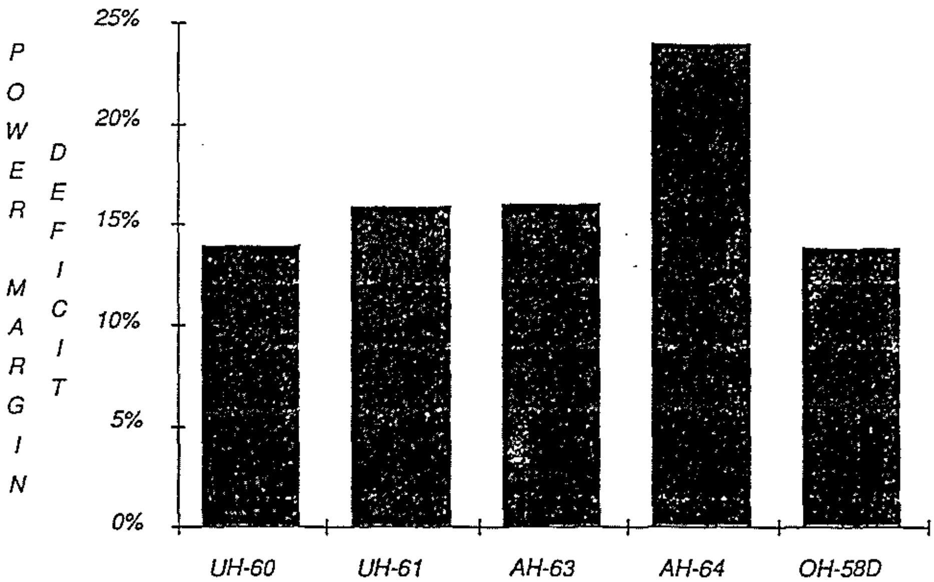
POWER MARGIN DEFICIENCY



NIKOLSKY '89

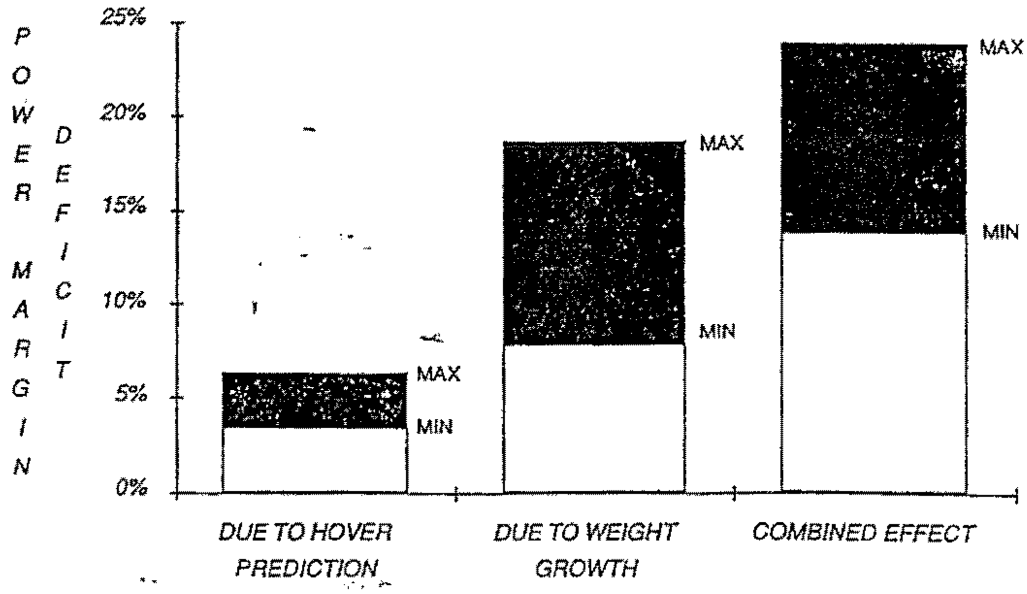
POWER MARGIN DEFICIENCY

(due to missing hover power and weight growth)



NIKOLSKY '89

POWER MARGIN DEFICIENCY
(excludes VROC considerations)



NIKOLSKY '89

IMPROVEMENTS IN PROCESS

govt. initiatives

- COMPREHENSIVE ANALYTICAL MODEL OF ROTORCRAFT AERODYNAMICS & DYNAMICS (CAMRAD)
- GENERAL ROTORCRAFT AEROMECHANICAL STABILITY PROGRAM (GRASP)
- SECOND GENERATION COMPREHENSIVE HELICOPTER ANALYSIS SYSTEM (2GCHAS)

industry initiatives

- COMPREHENSIVE PROGRAM FOR THEORETICAL EVALUATION OF ROTORCRAFT (COPTER)
- DYNAMIC SYSTEM COUPLER (DYSCO)
- COUPLED ROTOR / AIRFRAME VIB ANALYSIS PROG (SIMVIB)

validation thrusts

- DATA BASE INITIATIVES FOR CODE CORRELATION
  - --DNW WIND TUNNEL TESTS OF BOEING 360, MDHC HARP & UH-60 ROTORS
  - --NASA-ARMY UH-60 FLT TEST MEASUREMENT (MAY 89-SEPT 91)

NIKOLSKY '89

CONCLUSIONS

- *LACK OF REALISTIC / DETAILED ROTORCRAFT ANALYTICAL TOOLS RESULTS IN MANY CONFIG. CHANGES DURING FLT TEST.*
- *NEED EXTENSIVE WD TUNNEL PRE-DESIGN EFFORT*
  follow the fixed-wing commercial lead
- *HISTORY SUGGESTS - -*
  design for a 15%-20% power margin
- *A REVITALIZATION OF THE WORK OF BUILDING & VALIDATING IMPROVED ROTORCRAFT ANALYTICAL METHODS IS NEEDED*
- *IN THE INTERIM - - STICK WITH THE PROVEN*
  "competitive fly-off"
  FOR NEW AIR VEHICLES

NIKOLSKY '89