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STICK TRANSFER FUNCTION BRIEFING

J. R. BUYAN

HANDLE VIA BYEMAN
CONTROL SYSTEM
ONLY

AEROSPACE PILOT STUDY BRIEFING

- **PROBLEM STATEMENT**
  - / GENERAL TRANSFER FUNCTION (LOS/STICK DEFLECTION, d)

$$K_1 + \frac{K_2}{S} + \frac{K_3}{S^2} + \frac{K_4}{S^2} u\,(d-D)$$

  - / REQUIRED BY GE IN ORDER TO PERFORM OTHER STUDIES.
  - / AEROSPACE TO DO PRELIMINARY WORK, GE TO VALIDATE. in digital environment
- **TASK DEFINITION** - PRIMARY TASK IS RATE NULLING the FOLLOWING ERROR SOURCES.
  - / ALTITUDE AND PITCH, GYRO SCALE FACTOR - Cos^2 EFFECT
  - / SERVO RATE BIAS - CONSTANT RATE
  - / NOISE - LOW FREQUENCY RANDOM MOTION (NOT IN BUDGET)
  - / VIBRATION - NOT INCLUDED, DOESN'T AFFECT PERFORMANCE
  - / POSITION - NOT INCLUDED, DOESN'T AFFECT RATE NULLING PERFORMANCE
- **AEROSPACE SIMULATOR** (UNCLASSIFIED)
  - / DISPLAY - CRT, SQUARE SYMBOL, NON-ZOOM RETICLE, HOOD
  - / CONTROLS - STICK: 30° HALF ANGLE CONE, ANALOG PROCESSING
    GAIN CONTROL: 4 STEPS
  - / TASK - RATE NULL, 14 SECOND RUNS, 4 SECOND RESET, 2 INITIAL CONDITIONS
  - / SCORING - TIME TO GET BELOW RATE SPEC
    - STEADY STATE AVERAGE RATE ERROR LESS NOISE ERROR

AEROSPACE PILOT STUDY BRIEFING, CONT'D

- **PILOT STUDY RESULTS**

/ START WITH:

$$K_1 + \frac{K_2}{S} + \frac{K_3}{S^2} + \frac{K_4}{S^3}\ u\,(d\text{-}29^{\circ});\ \text{WITH AND WITHOUT GFM}$$

/ MINIMIZE STICK TYPES

$K_1 \neq 0$: JUMPY RESPONSE, FINGER NOISE

$K_3, K_4 \overset{=0}{\neq} 0$: if ~~REQUIRES~~ $K_2 \neq 0$: OSCILLATORY RESPONSE

NO GFM: REAL NOT APPARENT RATES DEFINE TASK

/ REDUCE STICK GAIN COMBINATIONS

$$\left[\frac{K_2}{S},\ \frac{K_2}{S} + \frac{K_3}{S^2},\ \frac{K_2}{S} + \frac{K_4}{S^2}\ u\,(d\text{-}29)\right]$$

K_2 ONLY: MUST BE LARGE ENOUGH TO CATCH ALL EXPECTED INITIAL CONDITIONS. THEREFORE, $K_2 \approx 4000$ (240 ur/s)

$K_2 + K_3$: LARGE K_2 GIVES FASTER INITIAL NULLING BUT POORER STEADY STATE PERFORMANCE

LARGE K_3 GIVES FASTER NULLING BUT INCREASES OVERSHOOTS

AEROSPACE PILOT STUDY BRIEFING, CONT'D

SET OF FINAL CANDIDATES:

K_2	K_3
2500 (150ur)	600 (36ur)
2000 (120ur)	800 (48ur)
1500 (90ur)	1000 (60ur)
1000 (60ur)	1200 (72ur)
500 (30ur)	1400 (84ur)

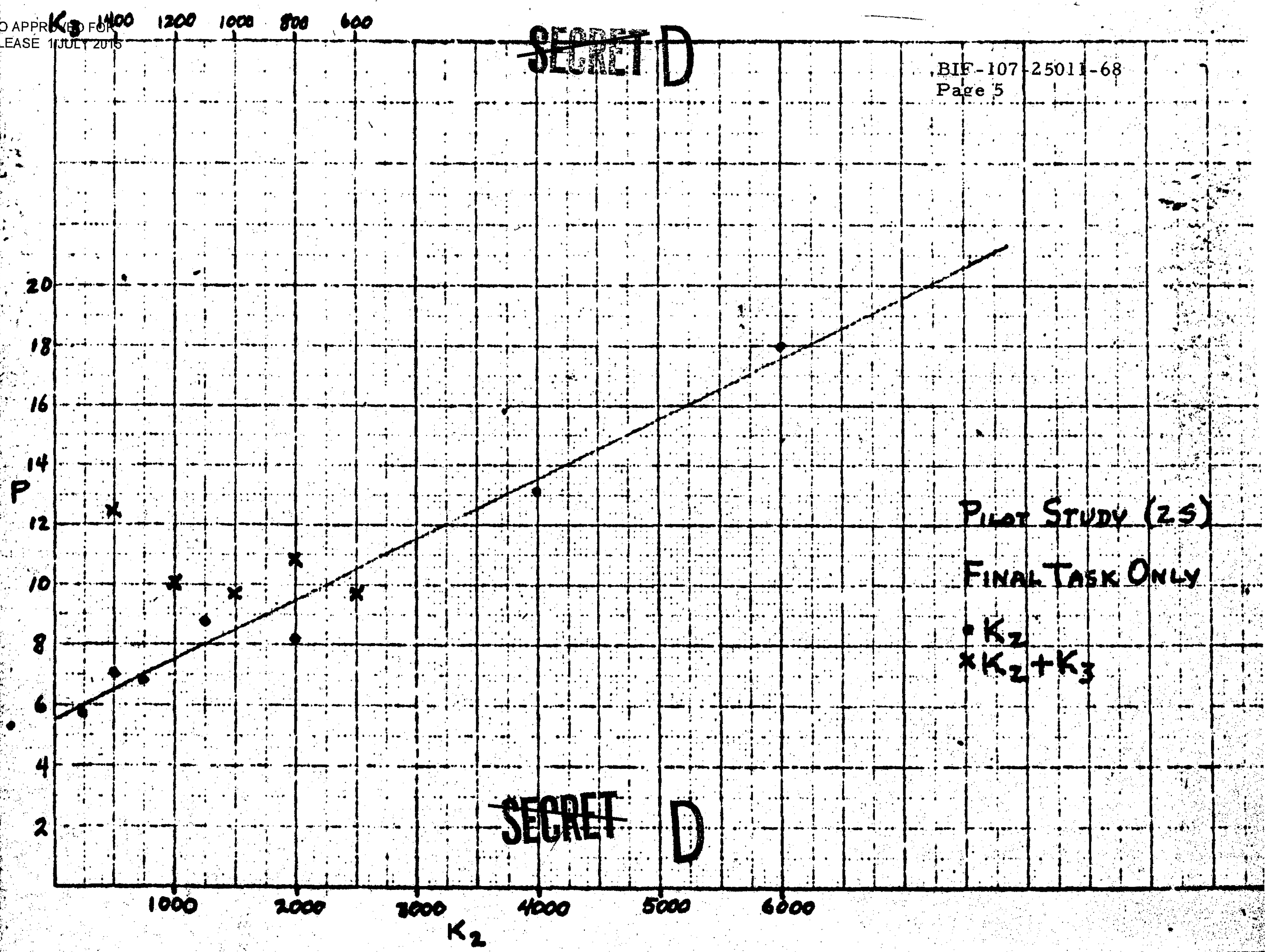
$K_2 + K_4 u$ $(d-29^{o})$: LARGE K_2 INCREASES STABILITY BUT REDUCES STEADY STATE PERFORMANCE

LARGE K_4 GIVES FASTER TIME BUT REDUCES STABILITY

SET OF FINAL CANDIDATES:

K_2	K_3
750 (45ur)	10,000 (600ur)
750	4000 (240ur)
750	2000 (120ur)
2000 (120ur)	10,000
2000	4000
2000	2000

~~SECRET~~ D



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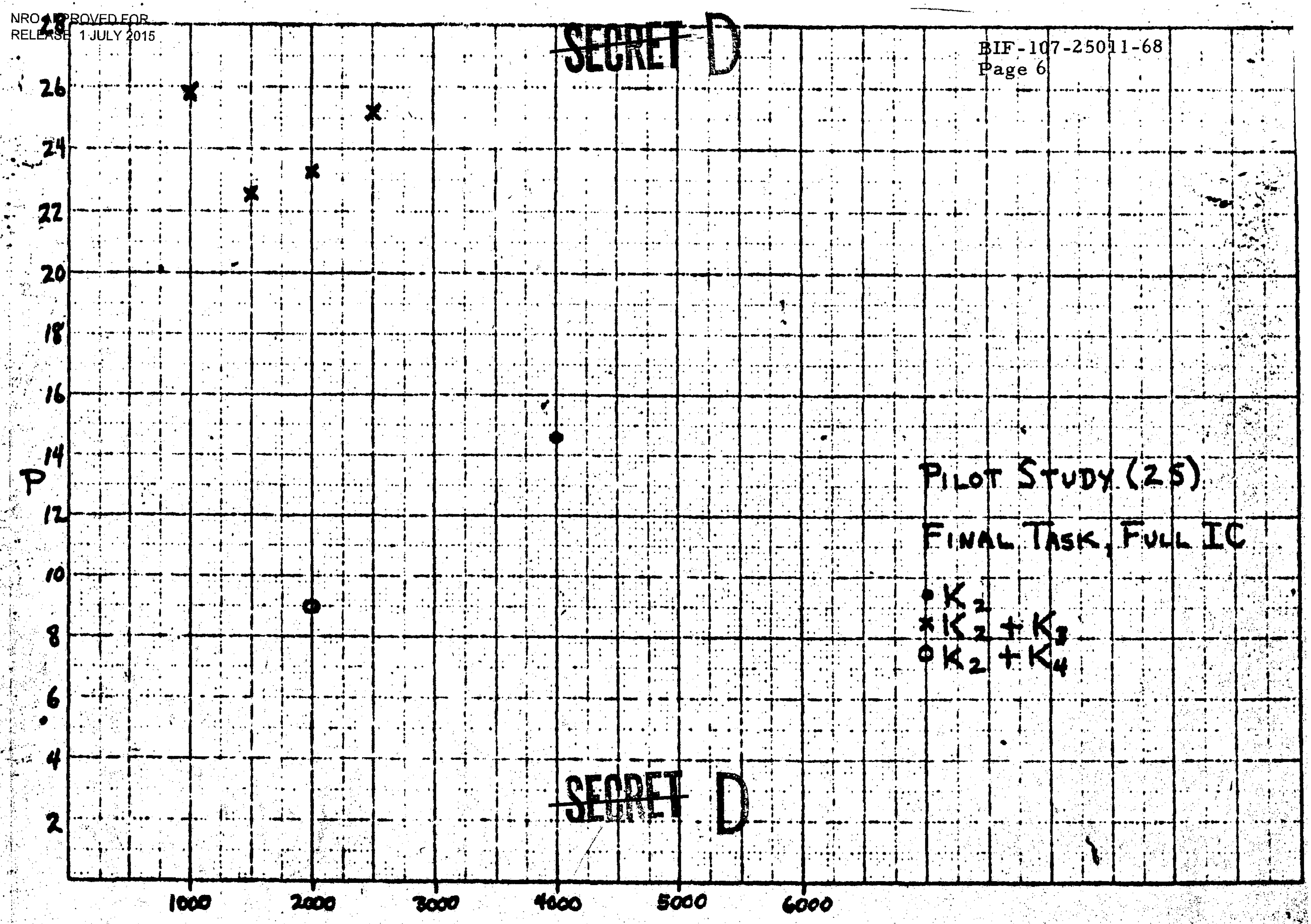

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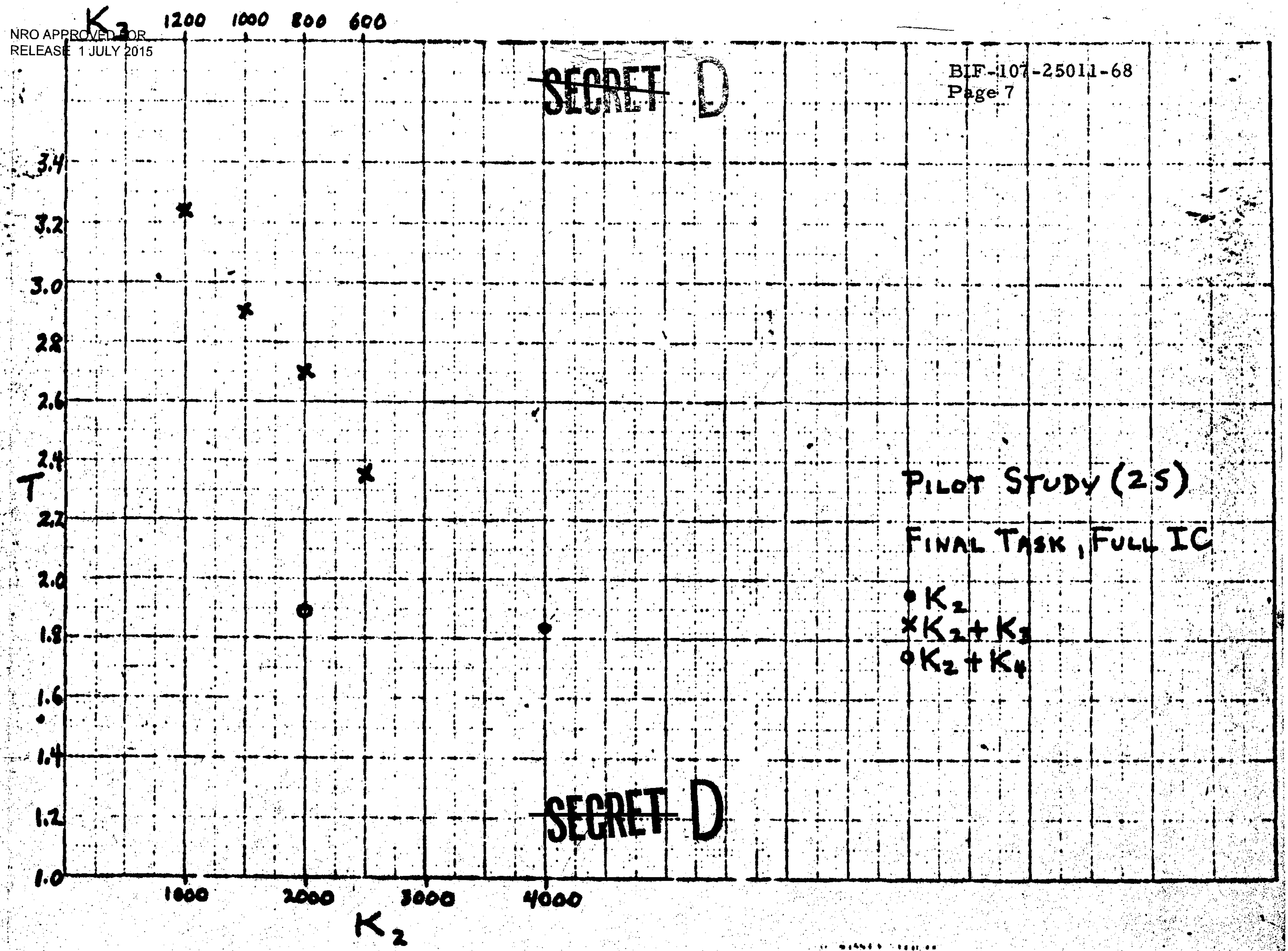

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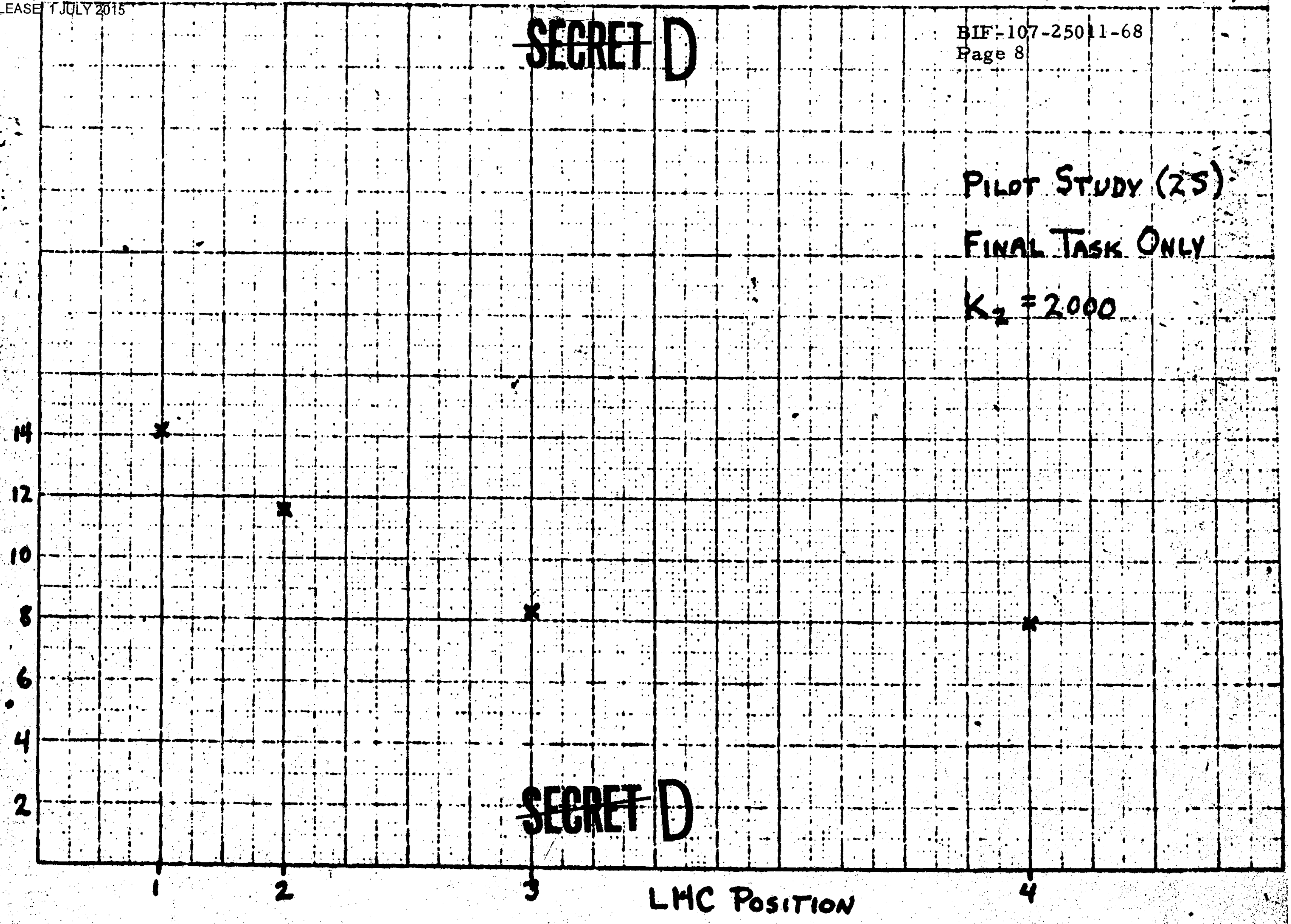

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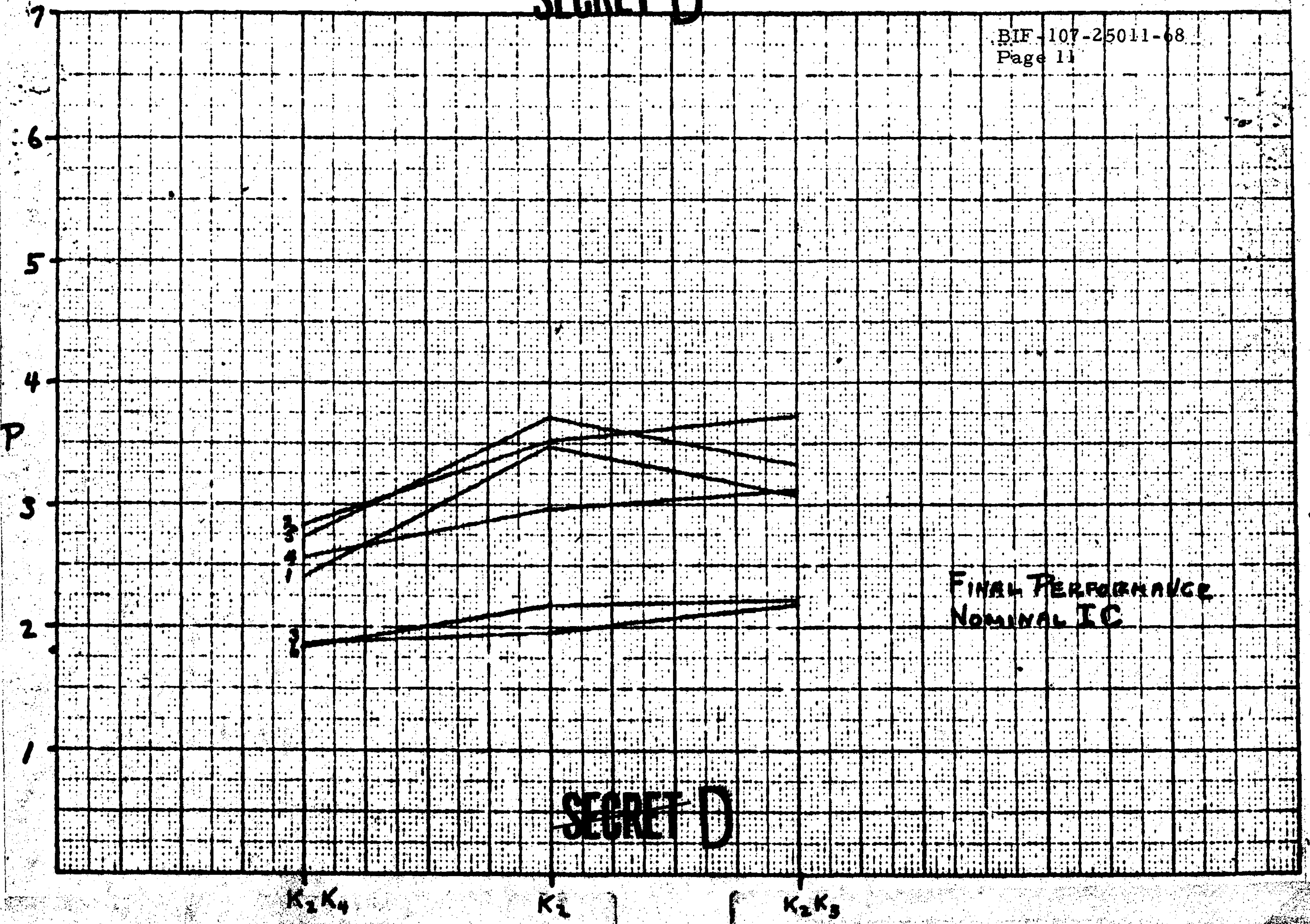
FORMAL STUDIES

- **EVALUATION**
  - / THREE TRANSFER FUNCTIONS (T)
    - (1) K_2 (240ur)
    - (2) $K_2 + K_3$ (120ur, 60ur)
    - (3) $K_2 + K_4$ (120ur, 240ur)
  - / TWO LEVELS OF INITIAL CONDITIONS (D)
    - (1) NOMINAL LEVEL (52. 1ur/s MAX)
    - (2) EXTREME LEVEL (215ur/s MAX)
  - / THREE BLOCKS OF DATA (B)
    - (1) TEN RUNS EACH (CONTAINS BOTH IC LEVELS)
  - / SIX SUBJECTS (S)
- **SCHEDULING**
  - / TRAINING - 5-9 HOURS TOTAL, 1 1/2-2 1/2 SESSIONS
  - / DATA RUNS - 1/2 SESSION, FOLLOWING PRACTICE
- **DATA ANALYSIS**
  - / TIME
  - / FINAL PERFORMANCE
- **VALIDATION**
  - / R-38

ANALYSIS OF VARIANCE (FINAL PERFORMANCE AND TIME)

SOURCES OF VARIATION	DEGREE OF FREEDOM	F RATIO ($p<.01$)
BETWEEN TRANSFER FUNCTIONS (T)	2	**
BETWEEN INITIAL CONDITIONS (D)	1	**
BETWEEN SUBJECTS (S)	5	**
INTERACTIONS:		
T x D	2	**
T x S	10	**
D x S	5	**
T x D x S	10	**
ERROR	504	
TOTAL	539	


7
6
5
4
P
3
2
1
5
3
4
1
3
2
K₂K₄
K₂
K₂K₃
FINAL PERFORMANCE
NOMINAL IC

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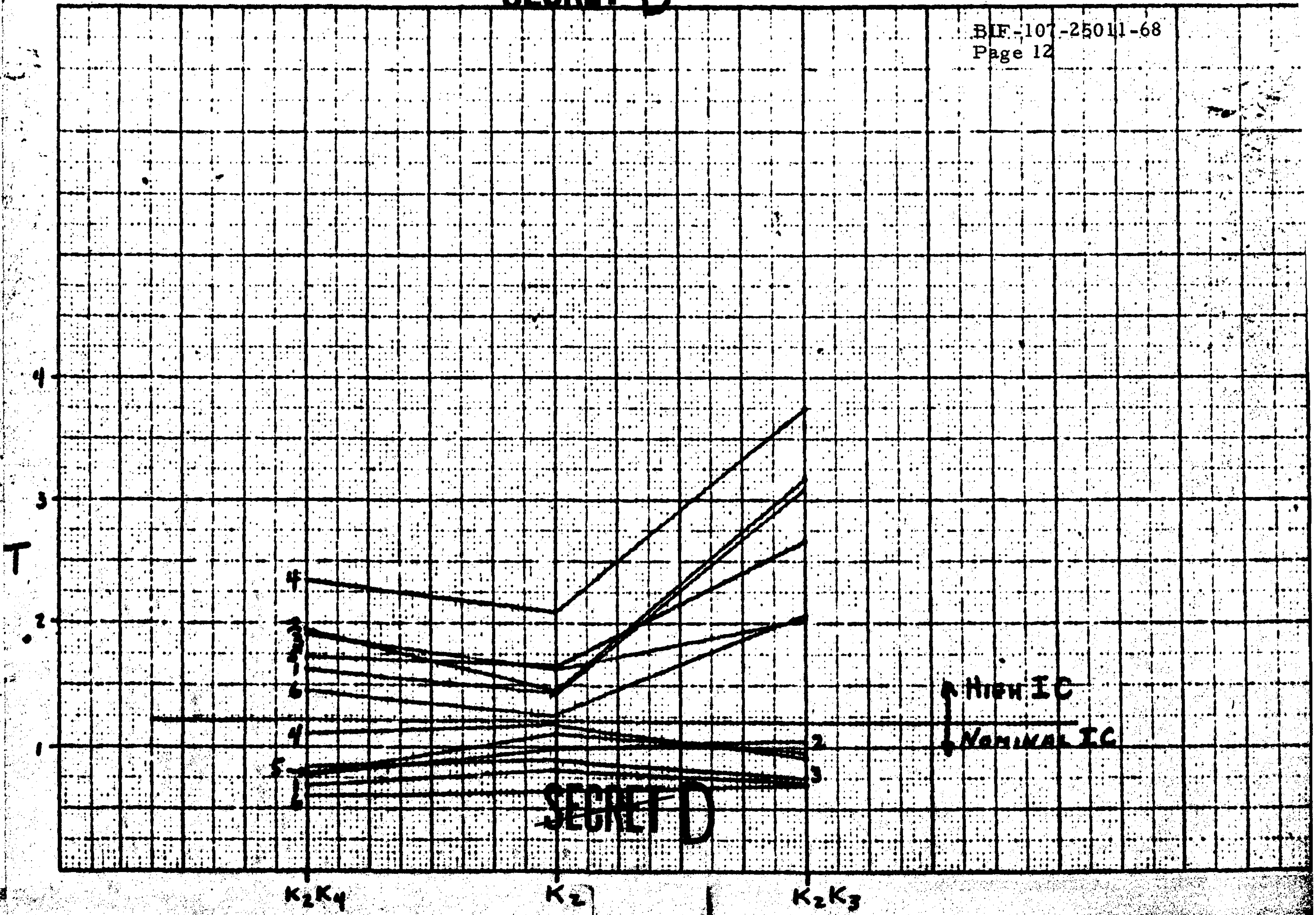

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FORMAL STUDY CONCLUSIONS

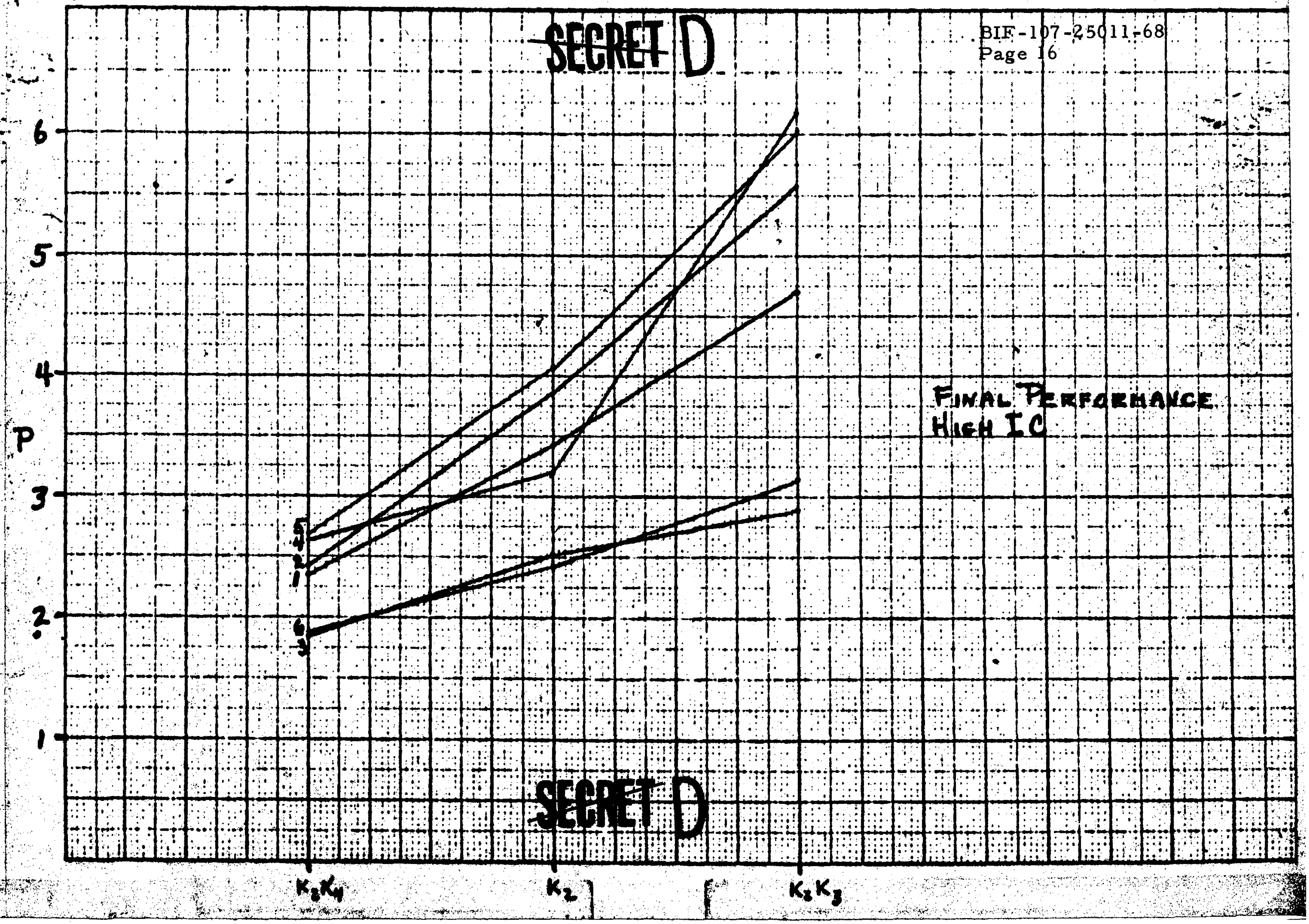
- RATE WITH END STOP ACCELERATION STICK HAS BEST OVERALL CAPABILITY AND FLEXABILITY
  - SIGNIFICANTLY BETTER RATE NULLING PERFORMANCE (INDEPENDENT OF INITIAL CONDITION MAGNITUDE)
  - TIME TO RATE NULL IS VERY GOOD
  - PREFERRED BY SUBJECTS
  - RANDOM NOISE INTERACTION MINIMIZED
  - HAS BEST TIME VERSUS RATE NULLING PEFORMANCE TRADEOFF FLEXABILITY
  - MOST EFFECTIVE PERFORMANCE AGAINST A WIDE RANGE OF INITIAL CONDITIONS

AEROSPACE EXTENTION TO MAXIMUM (SPECIFICATION) RATES

- **STICK GAINS REOPTIMIZED FOR SPEC RATES (540μr/sec)**
  - / **RATE STICK** — 600μr/sec max
  - / **RATE + ACC** — 480μr/sec + 240μr/sec^2 max ~~(PRELIMINARY)~~
  - / **RATE WITH END STOP ACC** — 240μr/sec + 720 600μr/sec^2 max ~~(PRELIMINARY)~~
- **PRELIMINARY RESULTS**
  - / **TIME TO NULL CONSISTENT WITH LOWER INITIAL CONDITION DATA**
  - / **RATE NULLING PERFORMANCE SLIGHTLY POORER**

GE VALIDATION STUDY

- SIMILARITIES
  - / THREE TRANSFER FUNCTIONS
  - / MAGNIFICATION
  - / SUBJECTS
  - / REAL TIME ANALOG DATA
  - / EXPERIMENTAL DESIGN
  - / INITIAL CONDITIONS INCLUDING EXTENSION TO SPEC RATES
- DIFFERENCES
  - / SCENE MATERIAL
  - / ADDITIONAL DIGITAL SCORING CAPABILITY
  - / AVE STICK SAMPLING RATE
  - / AVE DIGITAL STICK QUANTIZATION
  - / AVE EXTRAPOLATION (LINEAR)
  - / AVE PROCESSING DELAYS
  - / R-38 CAPSULE ENVIRONMENT


FINAL PERFORMANCE
HIGH IC
P
6
5
4
3
2
1
5
4
2
1
6
3
K_2K_4
K_2
K_2K_3

R-38 STATUS AND SCHEDULE

- SIMULATOR UPGRADING (TO JULY 8)
  - INCORPORATION OF AVE DIGITAL PROCESSING TECHNIQUES
  - SYSTEM ERROR ANALYSES, SCALING, CALIBRATION
  - ON LINE ANALOG SCORING
  - SOFTWARE PACKAGE DEVELOPMENT
- AF/AEROSPACE EVALUATION (WEEK OF JULY 8)
- FORMAL EXPERIMENT (BEGINNING JULY 15)

AEROSPACE ATS STICK TRANSFER FUNCTION STUDY

- OBJECTIVES
  - / OPTIMIZATION OF CENTERING TASK (PRIMARY EMPHASIS)
  - / OPTIMIZATION OF RATE NULLING PERFORMANCE (SECONDARY EMPHASIS)
- STICK CANDIDATES (HIGHER GAIN REQUIRED THAN FOR RATE NULLING)
  - / RATE ONLY - GOOD BUT HAS SIGNIFICANT FINGER NOISE
  - / RATE WITH ADDITIONAL END-STOP RATE - MOST FLEXIBLE
  - / RATE WITH END-STOP ACCELERATION - NOT OPTIMUM FOR THIS TASK
  - / RATE PLUS ACCELERATION - POOR
- TASK INTERPRETATION DIFFICULTIES
  - / WHEN IS CENTERING PERFORMED?
  - / CENTERING TIME VERSUS ACCURACY TRADEOFF
  - / ACTIVITY DETECTION VERSUS CENTERING TRADEOFF
- RECOMMENDATIONS
  - / PERFORM PROCEDURES DEFINITION AND/OR EXPERIMENT
  - / MAKE RATE WITH END-STOP RATE BASELINE ATS STICK TRANSFER FUNCTION

GENERAL AEROSPACE SIMULATOR RESULTS

- GENERALIZED KNOWLEDGE OF STICK TRANSFER FUNCTION TRADEOFFS
- REQUIREMENT FOR ON-LINE SCORING CAPABILITY
  - PERMITS RESPONSE TO DIFFERENTIAL LEARNING CHARACTERISTICS
  - PERMITS RAPID REDUCTION OF PARAMETER RANGES
  - IMMEDIATE RESULTS IMPROVE SUBJECT MOTIVATION
  - (PROVIDES KNOWLEDGE OF LEARNING STATUS)
  - SPEEDS OPTIMIZATION OF MOTOR SKILL TECHNIQUE
  - FATIGUE CAN BE QUICKLY DETECTED THROUGH PERFORMANCE DATA
- BETTER UNDERSTANDING OF CREW MOTOR SKILL LEARNING TIME
- IMPROVEMENT IN BASIS FOR TECHNICAL DIRECTION IN RELATED AREAS

FUTURE

- o CURRENT FOLLOW-ON EFFORT
  - / SIMULATION OF STICK SAMPLING CHARACTERISTICS ~~- AVAILABLE~~
  - / ~~SIMULATION OF STICK QUANTIZATION - UNDER DEVELOPMENT~~
    ~~FURTHER ATS STICK TRANSFER FUNCTION STUDIES AS REQUIRE~~
- o POTENTIAL EXPANSION TO HYBRID CAPABILITY
  - / HYBRID HARDWARE ~~TO BE~~ INSTALLED
  - / POSSIBLE USES: EXTRAPOLATION TECHNIQUES, OTHER AVE DIGITAL PROCESSING CHARACTERISTICS
- o FUTURE STUDY POSSIBILITIES
  - ~~/ STICK COUPLING~~
  - ~~/ DEROTATION EFFECTS~~
  - / [redacted]