Enclosure a

March 1, 1966

Technical Discussion of Proposal For "Needs Analysis and Solution Analysis" for the High Precision Stereo Comparator

1. Introductory Statement

Several studies have been conducted of the feasibility of developing a High Precision Stereo Comparator and of the possible problems to be encountered. The studies have recommended certain design choices. Prior to proceeding with detail design, it is desirable to review the various proposed design choices in the light of the current needs. Thus, a set of technical specifications for procurement can be prepared which will be accurately tailored to the requirements.

2. Needs Analysis

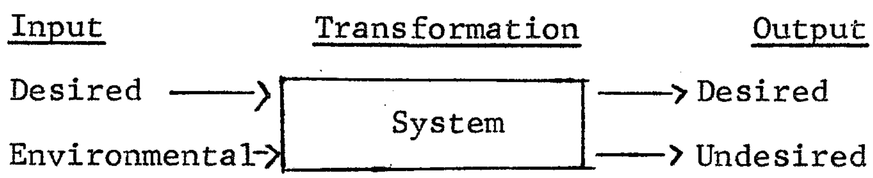
"Needs Analysis" is an engineering design term which refers to the technique of aggregating and summarizing all the various input requirements, stripping them to their basic essentials and converting them to an engineering statement of the problem. It is important that all the needs be considered and the following sources of needs will be included:

a.) Operator needs
b.) Maintenance needs
c.) Test and acceptance needs
d.) Measurement precision needs
e.) Measurement rapidity needs
f.) Computer needs
g.) Calibration needs
h.) Procurement (Contracting Officer) needs
i.) Shipping needs
j.) Installation needs
k.) Operator training needs
l.) Maintenance training needs
m.) Manufacturer's needs
n.) Building facilities needs

and others. The needs analysis provides a framework against which the proposed solutions can be tested.

3. Solution Analysis

The High Precision Stereo Computor can be considered as a system which receives inputs, performs a transformation and produces outputs.



The purpose of the Solution Analysis is to define a system which will optimize the output and be physically realizable and economically realizable. The design paths and design choices of the study programs are the solutions to be tested. They will be tested against:

a.) Easy acceptance of desired inputs
b.) Insensitivity to environmental inputs
c.) Maximizing desired outputs
d.) Minimizing undesired outputs

as well as the degree to which they meet the needs.

4. Procedure

The procedure will be to:

a.) Establish the needs by querying the sources and reducing the needs to quantitative engineering statements.

b.) Review the study reports to test the solutions against the needs and define the system in quantitative engineering terms.

c.) From the engineering statement of the problem and the system, prepare a set of specifications which will:

1.) Describe the Comparator
2.) Define installation requirements, environment and other engineering input required from Contracting Officer.
3.) Define the manufacturers output
4.) Define the test and acceptance standards.

[redacted]

Enclosure b March 1, 1966

Cost Estimate for Proposed

"Needs Analysis and Solution Analysis"

for the

High Precision Stereo Comparator

Work Statement

Perform a needs analysis and review study reports. Prepare an equipment technical description and a technical specification of performance and test and acceptance standards.

[redacted]

Delivery:

Specification report two months after authorization to proceed.

[redacted]

March 1, 1966

Enclosure c

Compilation of abstracts of [redacted] [redacted] studies relating to the High Precision Stereo Comparator.

Approved For Release 2005/06/23 : CIA-RDP78B04770A002900010002-9

October 30, 1964

Report on Orientation and Briefing Meeting

Subject: High Precision Stereo Comparator

Date & Place: October 15, 1964, at Washington, D.C., facility of Technical Representative of Contracting Officer

Attending: Chris M Jack E
John R John S

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The development objectives of a new submicron accuracy comparator were reviewed in considerable detail. The following discussion presents the conclusions of the meeting and also incorporates some further comments of my own.

1. GENERAL FEATURES

1.1 High speed measuring to submicron accuracy.

1.2 A general purpose workhorse device with maximum operator ease (to lessen fatigue) and efficiency (for rapid measuring capability).

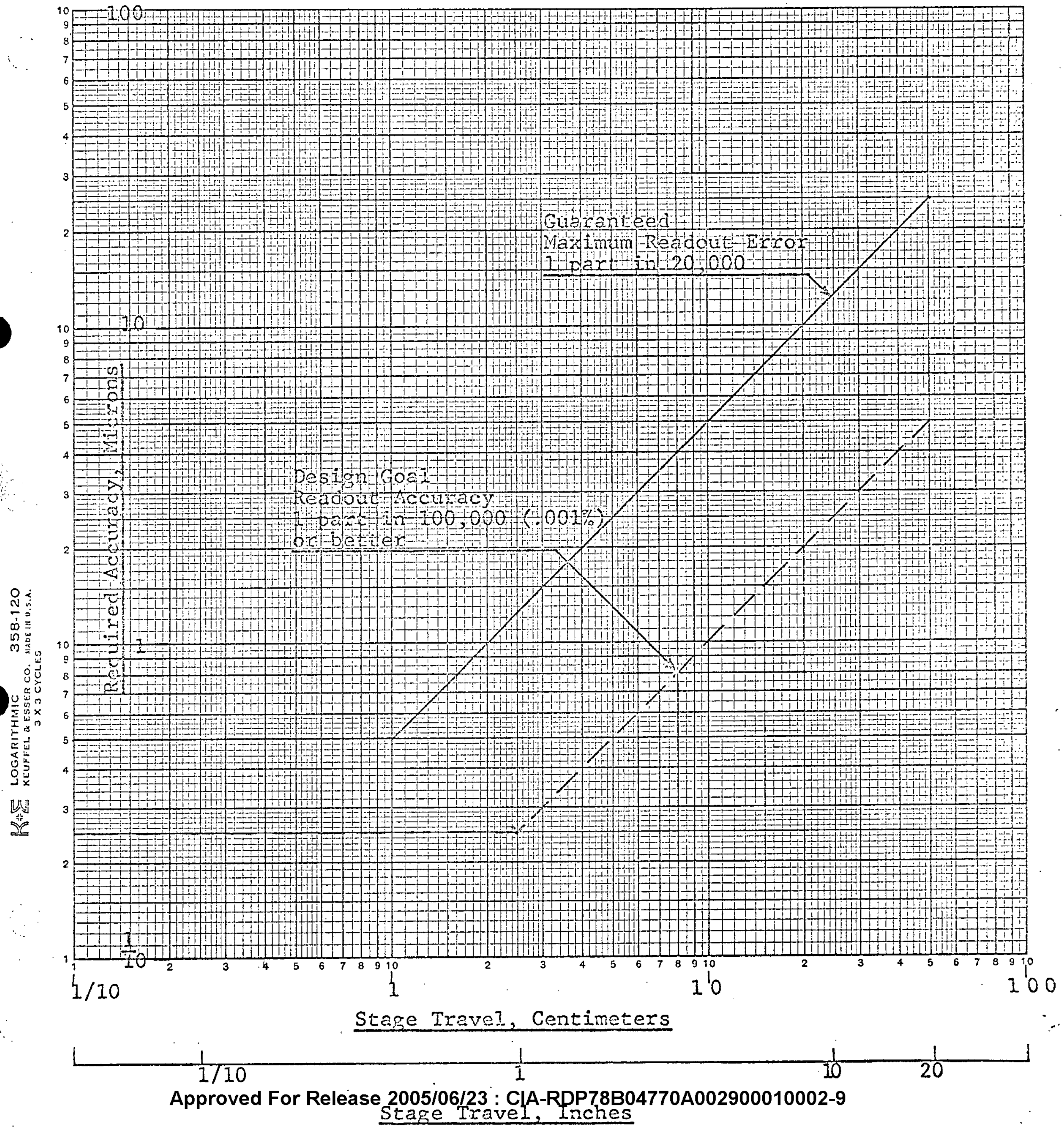
1.3 A stereo capability with each stage accommodating 25 cm x 50 cm (10" x 20") formats.

2. MEASURING ENGINE

2.1 The accuracy required over the full 25 cm and 50 cm travel or any part thereof is one part in 20,000 (with a design goal of one part in 100,000) or better except that the highest accuracy required will be $\pm$ 1/2 micron (design goal $\pm$ 1/4 micron) over small travels. See attached plot of accuracy required vs. measuring engine travel. The accuracy stated above refers to total readout repeatability accuracy and includes electronics errors, temperature drift, etc. It does not include operator pointing accuracy. In addition, the engine ways must be straight and orthogonal to 2 seconds of arc (9.7×10^{-6} radians), ie, the ways must contribute less than 5 microns error to a measurement over 20 inches of travel and less than 2-1/2 microns error to a measurement over 10 inches of travel.

October 28, 1964

MEASURING ENGINE ACCURACY REQUIREMENT



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November 9, 1964

Preliminary Technical Report

on

Item 1. Submicron Measurement Error Analysis.

Item 1 Work Statement: Evaluate the physical and metallurgical properties of materials used in measuring engine construction to determine comparative suitability to submicron measuring. Materials to be considered are: Meehanite, steel, granite, aluminum, magnesium, and glass.

Submitted by:

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Approved For Release 2005/06/23 : CIA-RDP78B04770A002900010002-9

Task II. Item 1. Preliminary Technical Report.

The materials under study are:

1. Meehanite
2. Steel
3. Granite
4. Aluminum
5. Magnesium
6. Glass

The materials may be more precisely defined as follows:

Meehanite. A high quality grey cast iron. The composition and properties are much more closely controlled than common structural cast iron. Meehanite is available in a variety of grades and the properties vary widely with grade.

Steel. Available in an enormous variety of alloys. For our purposes a low carbon, wrought, structural steel is representative.

Granite. Natural quarried granite is available in pink, grey, and black. Black granite is reportedly the hardest, most uniform, and best quality so we have used it in the evaluations.

Aluminum. Tooling plate is specially formulated and fabricated for high stability and low residual stresses. The cast type 300 is slightly better than wrought type. Therefore, the properties of Alcoa type 300 cast aluminum tool and jig plate have been used in the evaluation.

Magnesium. Dow Alloy AZ 31 B is specially fabricated in tooling plate with high stability and low residual stresses. Alloying elements are 1% zinc and 0.45% manganese.

Glass. Fuzed quartz was selected as the glass best suited to measuring engine applications.

The properties covered in detail in this preliminary report are:

1. Modulus of elasticity (stiffness).
2. Density (weight).
3. Ratio of stiffness to weight.
4. Thermal conductivity.
5. Thermal coefficient of linear expansion.
6. Thermal capacity.
7. Ratio of thermal expansion to thermal capacity.

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April 30, 1965

2nd Preliminary Technical Report

Item 1. Submicron Measurement Error Analysis

Item 1 Work Statement: Evaluate the physical and metallurgical properties of materials used in measuring engine construction to determine comparative suitability to submicron measuring. Materials to be considered are: Meehanite, steel, granite, aluminum, magnesium, and glass.

Submitted by:

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2nd Preliminary Technical Report

CONTENTS

Approved For Release 2005/06/23 : CIA-RDP78B04770A002900010002-9

1. Summary

In the first preliminary technical report, dated November 9, 1964, certain physical and metallurgical properties were examined to determine which of the following materials are best suited to measuring engine construction:

(1) Meehanite cast iron
(2) Structural steel
(3) Black granite
(4) Aluminum tooling plate
(5) Magnesium tooling plate
(6) Fuzed quartz glass

In subsequent study it was observed that beryllium had properties superior to steel and that certain special glasses had zero thermal expansion. It was therefore decided to include beryllium metal and Cer-Vit C-100 glass in the evaluation. Dimensional stability was the principal criterion and the thermal stability and structural rigidity of the materials were considered. The order of preference was found to be:

a) Thermal dimensional stability

Thermal dimensional stability	Rank Index*
(1) Cer-Vit C-100 glass	0.00 (ideal)
(2) Quartz	0.10
(3) Beryllium	1.00
(4) Granite	1.16
(5) Aluminum	2.08
(6) Meehanite	3.74
(7) Steel	3.86
(8) Magnesium	4.04 (least desirable)

b) Structural rigidity per unit weight

Structural rigidity per unit weight	Rank Index*
(1) Beryllium	1.00 (most desirable)
(2) Cer-Vit C-100 glass	4.48
(3) Steel, aluminum, and magnesium	6.23
(4) Granite	8.26 to 5.17
(5) Meehanite	9.35 to 7.15
(6) Quartz	11.35 (least desirable)

c) Structural rigidity under external loads

Structural rigidity under external loads	Rank Index*
(1) Beryllium	1.00 (most desirable)
(2) Steel	1.45
(3) Meehanite	1.83 to 2.40
(4) Cer-Vit C-100	3.13
(5) Aluminum	4.07
(6) Magnesium	6.46
(7) Quartz	9.55 (least desirable)

*Rank index is based on beryllium = 1.00 with larger values indicating reduced effectiveness.

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[redacted]

June 30, 1965

MAILING ADDRESS:

STAT [redacted]

Task II, Item 1, 3rd Preliminary Technical Report

Item 1. Submicron Measurement Error Analysis

WORK STATEMENT

Evaluate the physical and metallurgical properties of materials used in measuring engine construction to determine comparative suitability to submicron measuring. Materials to be considered are: Meehanite, steel, granite, aluminum, magnesium, and glass, and other materials that may be particularly suitable.

Evaluate physical properties and structural concepts appropriate to achievement of vibration levels and structural rigidity compatible with submicron measuring requirements. Evaluate methods of measuring the small vibration levels expected in a high performance structure.

Reports No. 1 and No. 2 dealt with the physical and metallurgical properties of materials. This report, No. 3, deals with structural rigidity and vibration control.

Submitted by:

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Task II, Item 1, 3rd Preliminary Technical Report

CONTENTS

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[redacted]

July 30, 1965

MAILING ADDRESS:

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[redacted]

Task II, Item 1, 4th Preliminary Technical Report

Item 1. Submicron Measurement Error Analysis

WORK STATEMENT

Evaluate the physical and metallurgical properties of materials used in measuring engine construction to determine comparative suitability to submicron measuring. Materials to be considered are: Meehanite, steel, granite, aluminum, magnesium, and glass, and other materials that may be particularly suitable.

Evaluate physical properties and structural concepts appropriate to achievement of vibration levels and structural rigidity compatible with submicron measuring requirements. Evaluate methods of measuring the small vibration levels expected in a high performance structure.

Reports No. 1 and No. 2 dealt with the physical and metallurgical properties of materials. Report No. 3 dealt with structural rigidity and vibration control of the machine structure. This report, No. 4, presents results of a computer analysis of building floor vibration frequency.

Submitted by:

STAT

[redacted]

1. SUMMARY

A free vibration analysis of one typical bay of an upper story floor of a building has been made. The floor is a multiple bay slab-column structure. The purpose of the analysis was to determine the fundamental and higher mode frequencies of the floor slab. Knowledge of the floor frequencies is important to determine the interaction of floor with the vibration isolation system of a projected submicron measuring machine.

The assumed floor structural dynamic model is shown in Figure 1a and 1b. The analysis was carried out by an existing IBM 7094 routine. The result of the computation indicates the fundamental frequency is 15.6 cycles per second. If the data on the floor construction is accurate the analysis will yield a 10% accurate fundamental frequency. The fundamental frequency may therefore vary from 14 to 17 cps. The computed 15.6 cps. fundamental floor frequency is much lower than the 20 cps. to 65 cps. anticipated in report No. 3. If the floor frequency is that low, it would necessitate a machine vibration isolator system of much lower natural frequency than the 8 cps. suggested in report No. 3.

Before proceding further on the structure evaluation, the floor frequencies will be reexamined with more accurate data on the floor construction.

2. STRUCTURAL DYNAMIC MODEL OF THE FLOOR SLAB

Figure 1a shows the grid framework of the floor slab.

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September 30, 1965

Mailing Address

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[redacted]

Task II - Item 1 Submicron Measurement Error Analysis

Comments on some Vibration Measurements

WORK STATEMENT

Evaluate the physical and metallurgical properties of materials used in measuring engine construction to determine comparative suitability to submicron measuring. Materials to be considered are: Meehanite, steel, granite, aluminum, magnesium, and glass, and other materials that may be particularly suitable.

Evaluate physical properties and structural concepts appropriate to achievement of vibration levels and structural rigidity compatible with submicron measuring requirements. Evaluate methods of measuring the small vibration levels expected in a high performance structure.

Reports No. 1 and No. 2 dealt with the physical and metallurgical properties of materials. Report No. 3 dealt with structural rigidity and vibration control of the machine structure. Report No. 4 presented results of a computer analysis of building floor vibration frequency. This technical note contains comments on building floor vibration measurements.

Submitted by:

[redacted]

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Technical Note on Building Floor Vibration Measurements

In technical report no. 4, dated July 30, 1965, the results were presented of a computer analysis of the free-vibration mode of a typical bay in the building in which the submicron measuring instrument will be used. The computer analysis indicated that the fundamental mode of the floor slab vibration was 15.6 cps. This is considerably lower than the 20 cps to 65 cps previously estimated from manual calculations. The lower floor slab frequency makes it much more difficult to achieve effective vibration isolation between the floor slab and the measuring instrument. Whereas we had previously believed that an 8 cps mount would be satisfactory (for floor frequencies of 30 cps and higher), it now appears that a 2 cps mount is necessary for 15 cps input from the floor. Fig. 1 illustrates the greater effectiveness of a 2 cps mount.

An attempt was made to detect floor slab resonant frequencies but results were questionable. During the day we were not able to excite the floor slab above the background level. A test was made in the early morning when the background level was low and 30 cps, 60 cps and 90 cps was detected. The results are suspect because we could not be assured that we were not measuring stray voltages from the 60 cps building power.

A report on Bureau of Standards floor vibration measurements made in 1960 was reviewed. The report indicated that on the second floor, the vertical component could go as low as 5 to 7 cps and horizontal components as low as 3 to 5 cps. Effective isolation of frequencies that low is hopeless. In fact we hesitate to recommend a mount as soft as 2 cps. A mount suspended on vibration isolators that soft is awkward for an operator to work on because small forces create large excursions. For an 8 cps mount the 1g excursion is only 0.165

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February 1, 1966

Task II Item 8 Technical Report

LASER METROLOGY

Work Statement: Investigate the use of the helium neon gas laser for measuring engine applications. The use of a laser interferometer and fringe counting for measuring length has problems with counting rate and with vibration and thermal gradients interfering with counting. There are certain precautions which must be taken.

This report presents an analysis of the magnitude of potential errors in applying a laser interferometer to a high precision measuring engine.

Submitted by:

STAT [redacted]

Approved For Release 2005/06/23 : CIA-RDP78B04770A002900010002-9

1. INTRODUCTION

1.1 Summary

An analytical investigation was made of the problems associated with use of an interferometer for precision measurement of length. The investigation was oriented toward the usage of the helium-neon gas laser for the interferometer light source. The precision criterion was the measurement of lengths up to 1 meter to an accuracy of ¼ micron. Interferometers have been used for many years for the precise measurement of short lengths. Pre-laser light sources permitted precise measurement of lengths up to about 10 cm. Laser light sources permit precise measurement of lengths of at least several meters and perhaps several hundred meters.

Quantitive estimates are presented in this report of the effect on the precision of measurement of: wavelength determination, mirror alignment, atmospheric variations, particles in the beam, traversing speed, polarization, spectral purity and vibration. Spectral purity (i.e,, spatial coherence) and mirror alignment are of paramount importance. Only traversing speed presents unresolved problems and vibration of course requires special analysis of detail structure.

The classic Michelson arrangement with minor modifications has proved most practical for metrology. The Fabry-Perot arrangement is well suited only to the measurement of a fixed length.

1.2 Conclusions

There is no doubt as to the technical feasibility of using a helium-neon gas laser interferometer to make