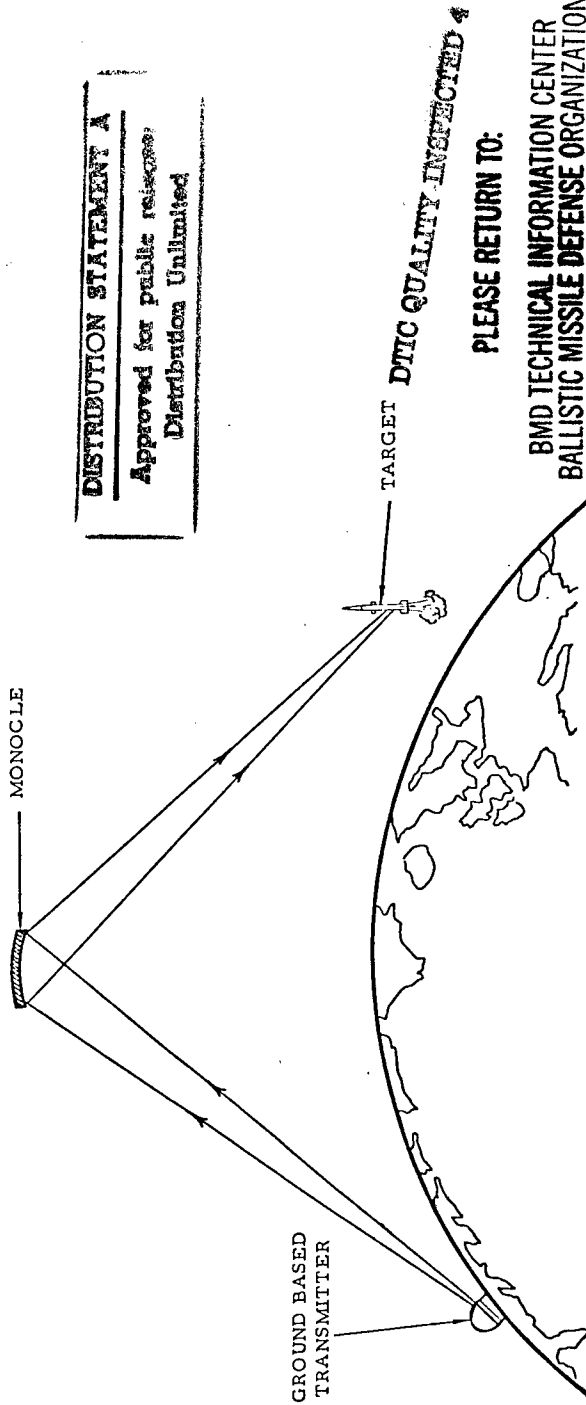


THE OPTICAL SCIENCES COMPANY
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**MONOCLE POINTING CONTROL:
ALIGNMENT MAINTENANCE FOR A
NULL-SEEKING ANGLE BISECTOR SENSOR**



David L. Fried

June 1981

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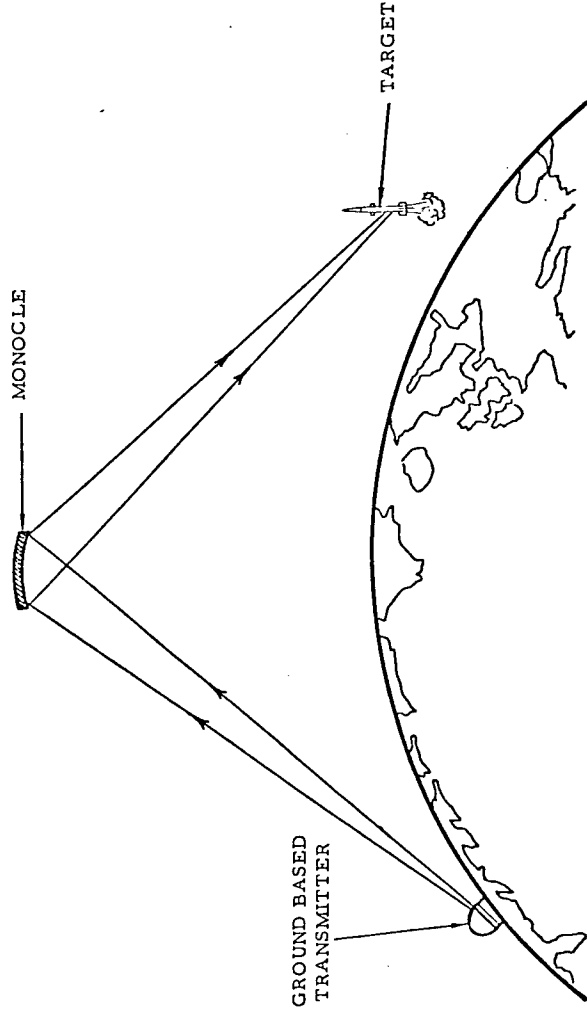
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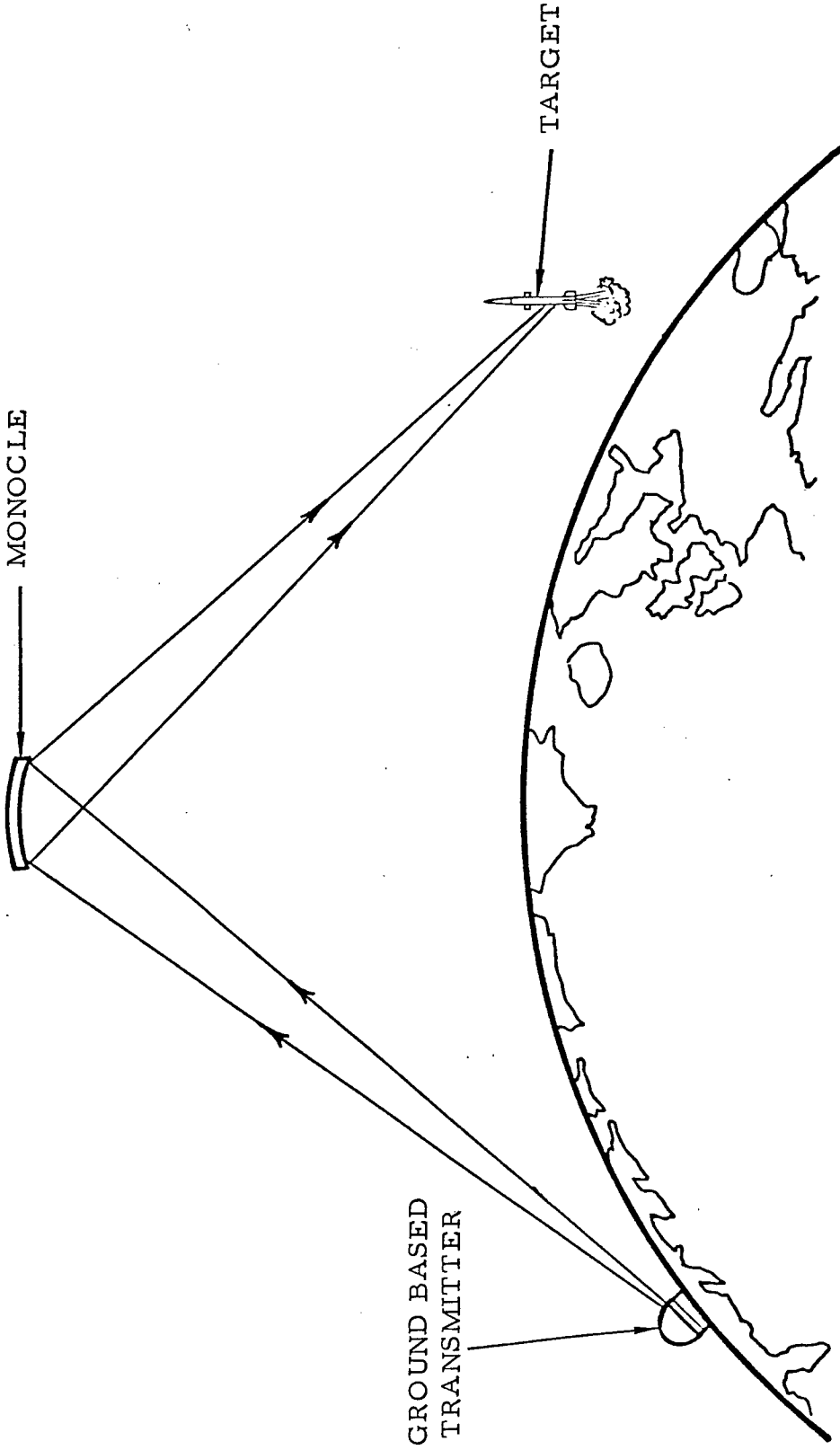
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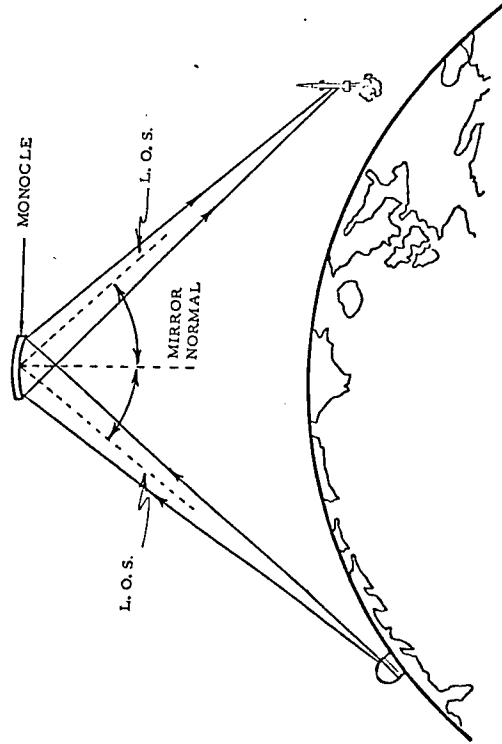
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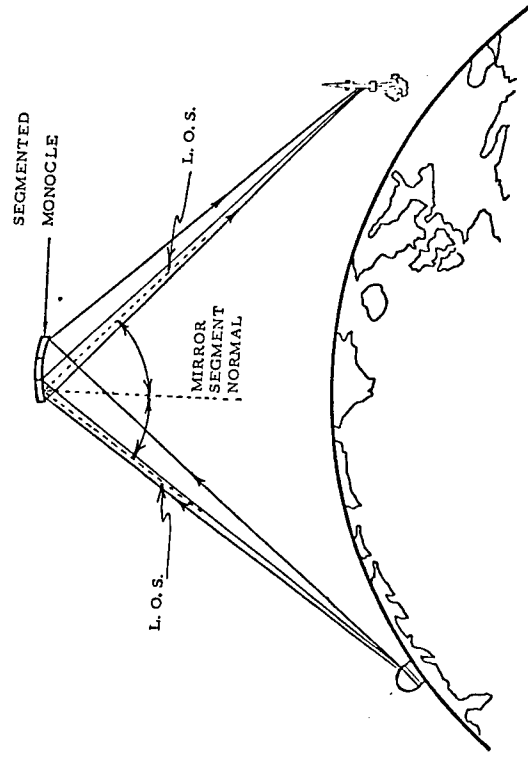


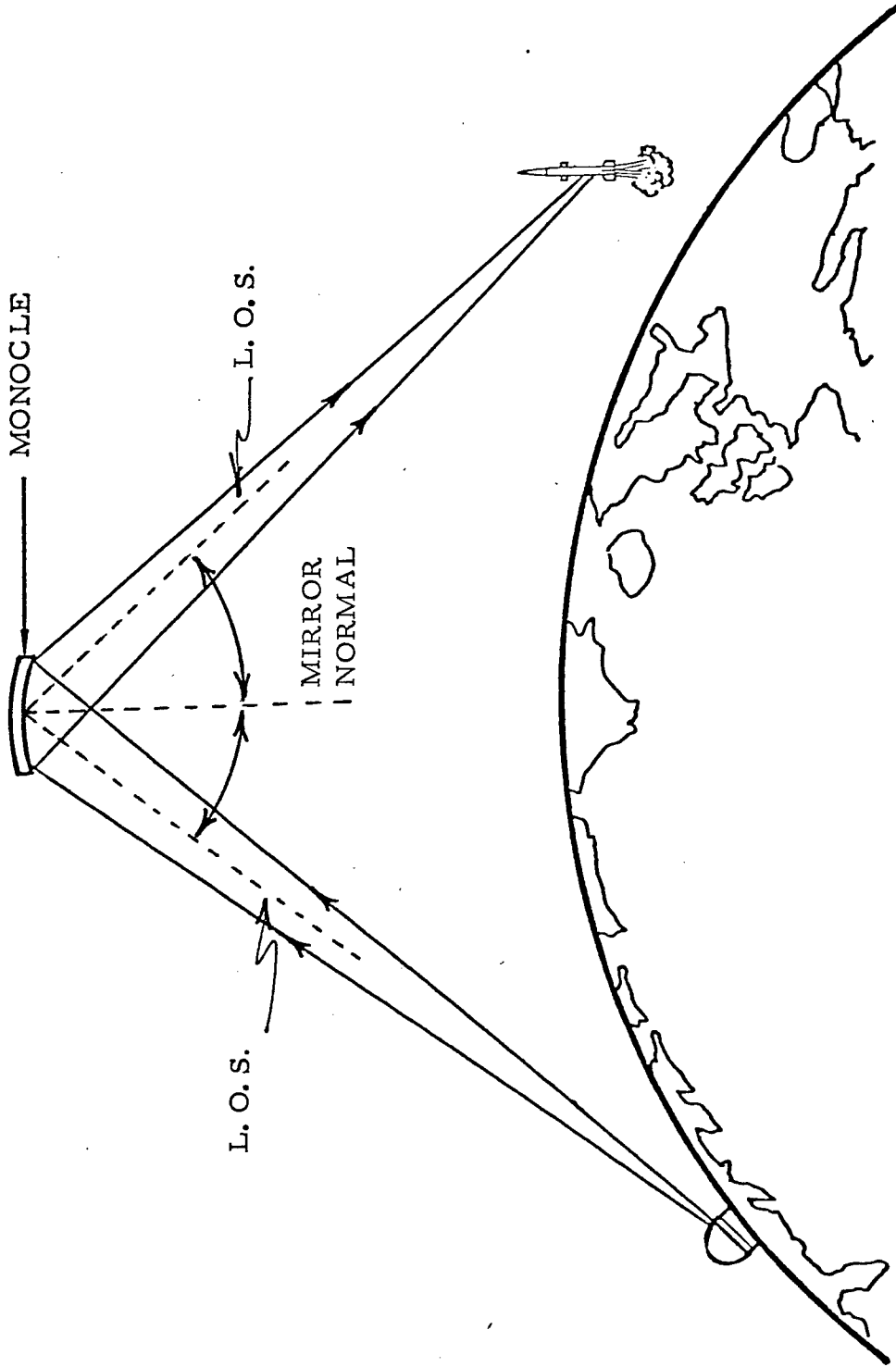
REQUIREMENT FOR ANGLE BISECTION

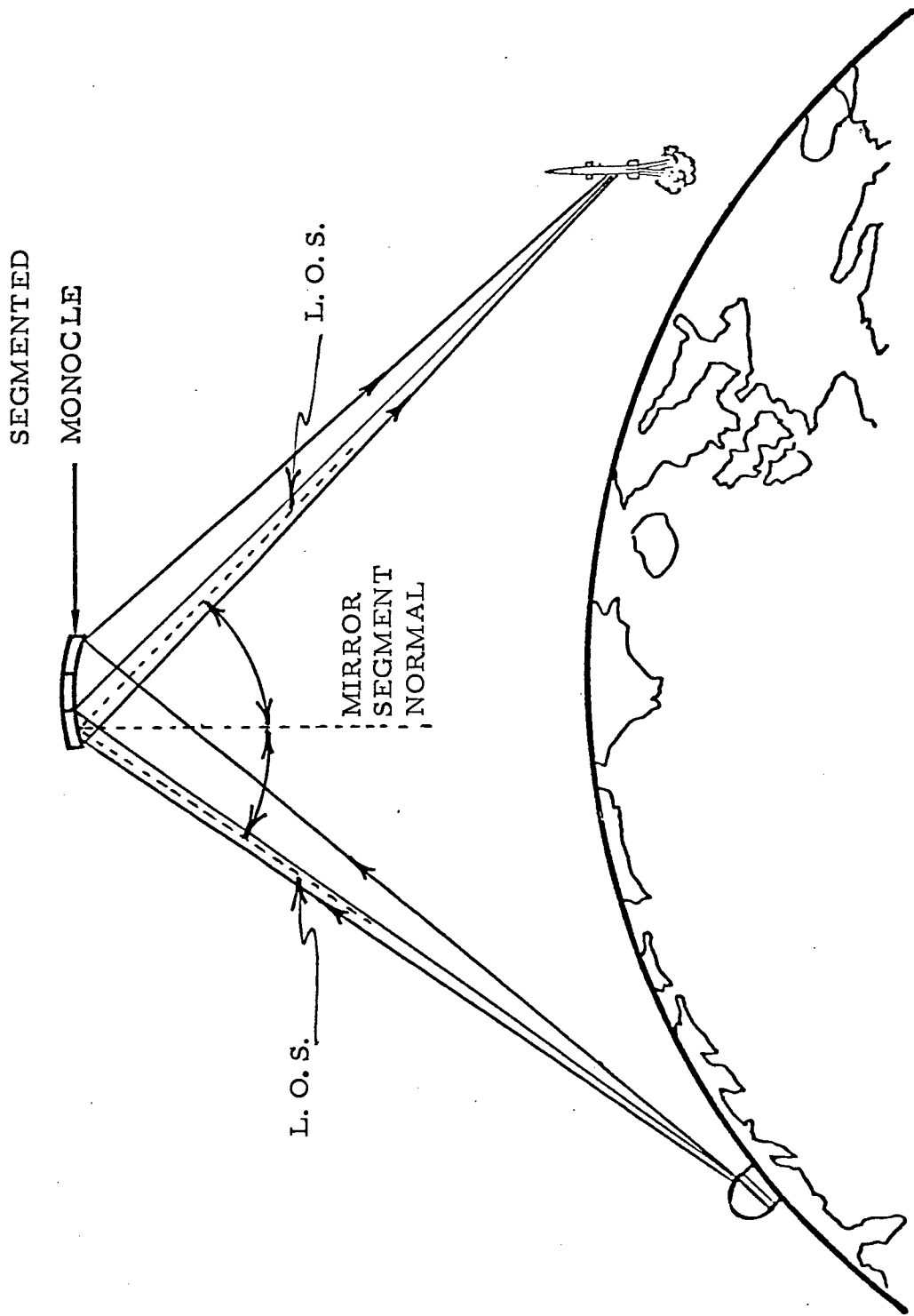
IF MONOCLE IS MONOLITHIC
THE MIRROR SURFACE NORMAL
MUST BISECT THE ANGLE FORMED
BY THE TWO LINES-OF-SIGHT.



IF MONOCLE IS SEGMENTED
THE SURFACE NORMAL OF EACH
MIRROR SEGMENT MUST BISECT
THE ANGLE FORMED BY THE TWO
LINES-OF-SIGHT.

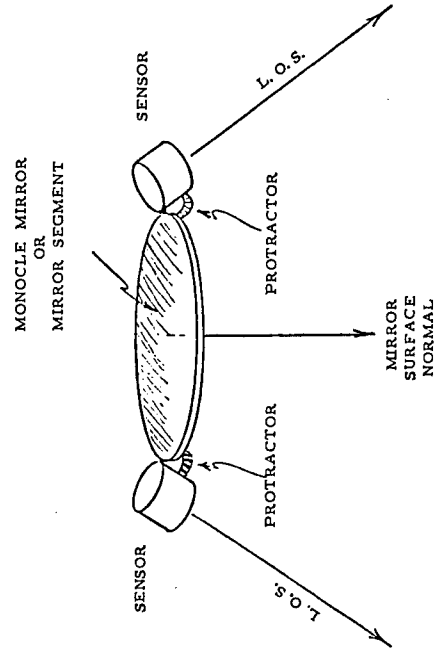




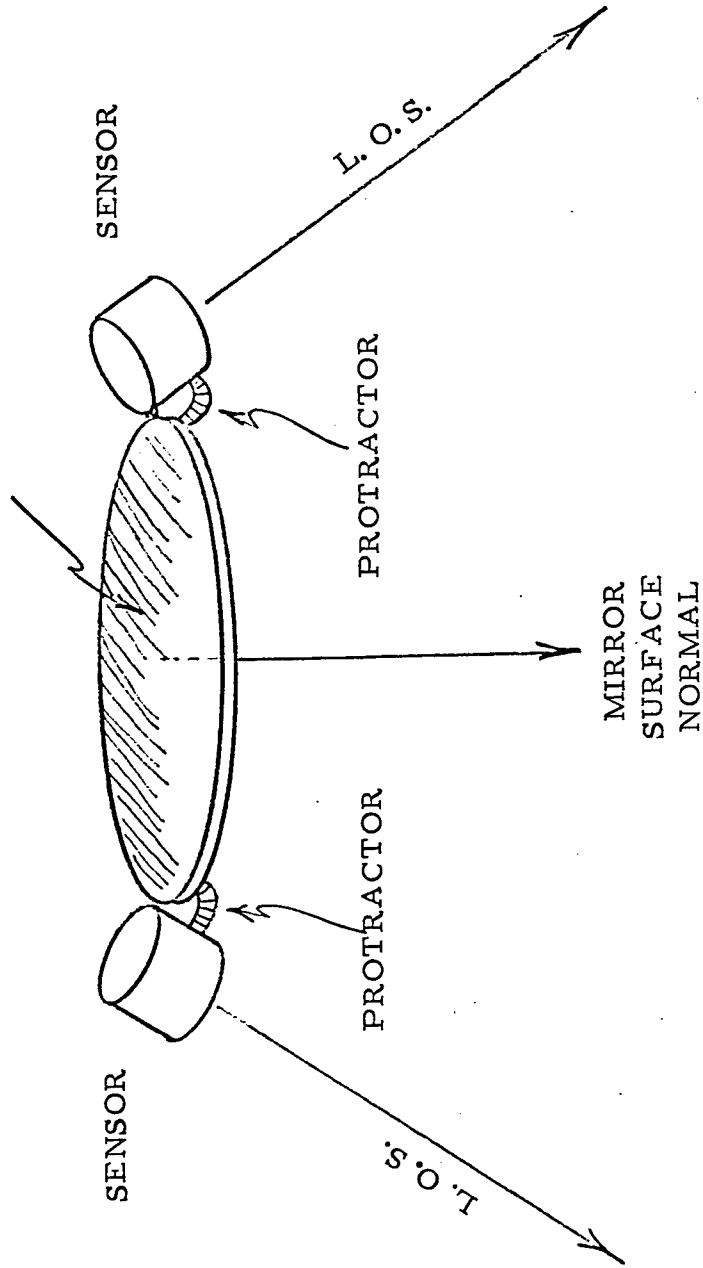


ANGLE BISECTION WITH A "PROTRACTOR"

- ASSUME MIRROR (SEGMENT) RIGIDLY RELATES THE TWO PROTRACTORS TO EACH OTHER AND TO THE MIRROR SURFACE NORMAL.
- PROTRACTOR ACCURACY HAS TO BE $\approx 10^{-7} \leftrightarrow 10^{-8}$ rad AND COVER A RANGE OF $\approx 10^{-1}$ rad. PROTRACTOR READING IS A 20 \leftrightarrow 23 bit WORD.
- THE PROTRACTOR (REAL OR VIRTUAL) IS A QUESTIONABLE SOLUTION TO THE POINTING PROBLEM.

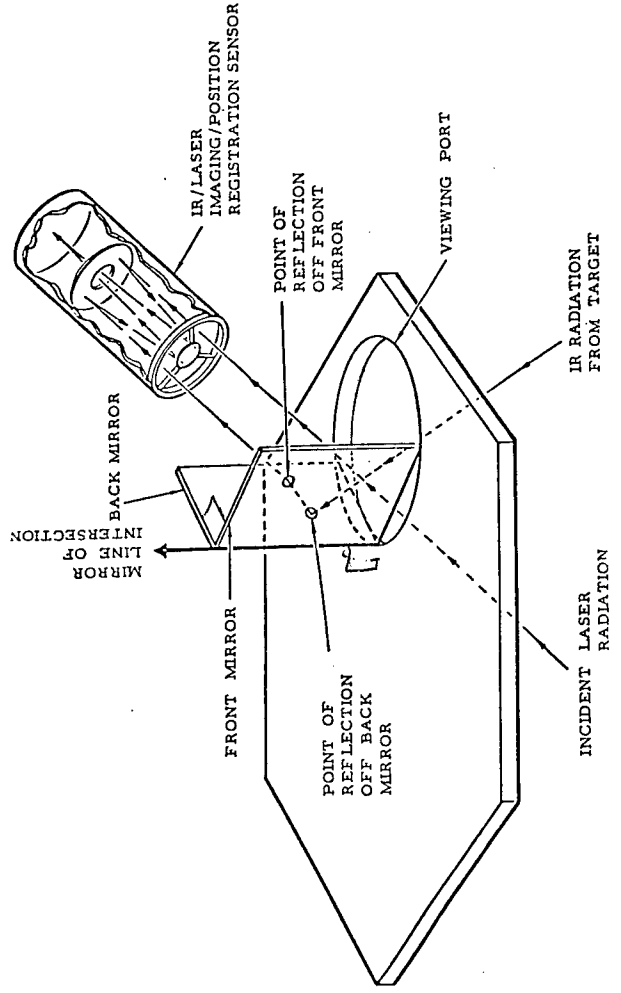


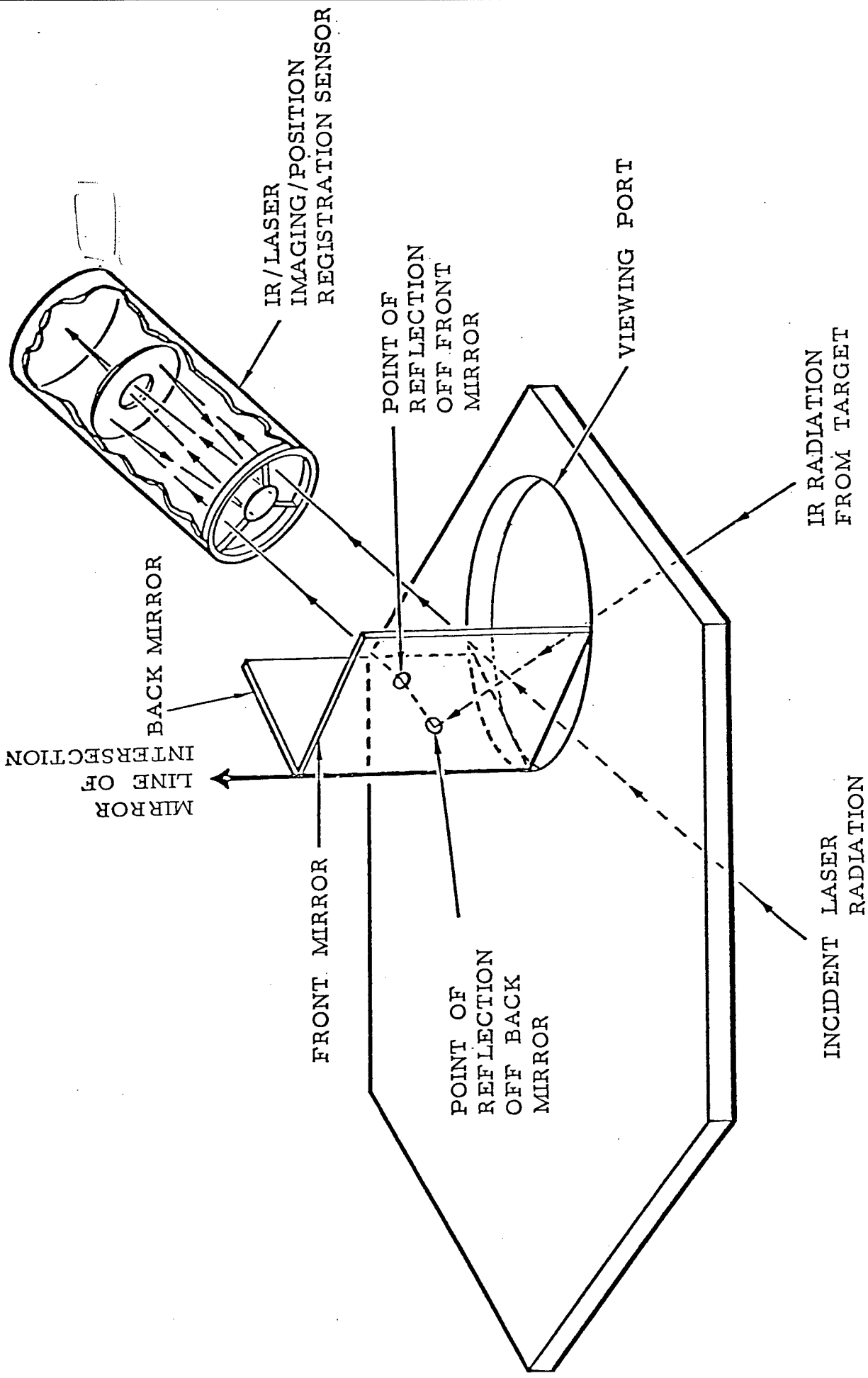
MONOCLE MIRROR
OR
MIRROR SEGMENT



ANGLE BISECTION WITH A NULL-SEEKING SENSOR

- FRONT AND BACK MIRRORS (BACKSIDE ALIGNMENT MIRRORS) ARE PERPENDICULAR TO EACH OTHER, AND TO THE LARGE MIRROR SURFACE.
- THIS INSURES THAT IF THE LASER RADIATION REACHING THE SENSOR HAS ZERO DIFFERENCE IN DIRECTION RELATIVE TO THE DIRECTION OF THE TARGET'S IR RADIATION REACHING THE REGISTRATION SENSOR (AFTER REFLECTING OFF THE FRONT AND BACK MIRRORS), THEN THE LARGE MIRROR SURFACE NORMAL BISECTS THE ANGLE BETWEEN THE TWO LINES-OF-SIGHT.





IMPLEMENTATION PROBLEMS

- TWO-COLOR (LASER/IR) SENSOR WITH $\approx 10^{-7} \leftrightarrow 10^{-8}$ rad
REGISTRATION BETWEEN COLORS. 1μ (cm)
- BACKSIDE ALIGNMENT MIRRORS' ORIENTATION TOLERANCE
MUST BE SET AND MAINTAINED WITH $10^{-7} \leftrightarrow 10^{-8}$ rad ACCURACY.

SETTING ORIENTATION OF BACKSIDE ALIGNMENT MIRRORS

- USE GROUND RECEIVER/IR-BEACON STATION WITH RF TELEMETRY TO RELAY SATELLITE.
- USING TELEMETRY FROM GROUND STATION GET RELAY MIRROR (SEGMENT) ORIENTED SO (LOW POWER SAMPLE OF) HEL FROM GROUND TRANSMITTER WILL BE DIRECTED TO THE GROUND RECEIVER.
- ORIENT BACKSIDE ALIGNMENT MIRRORS SO IMAGE OF IR BEACON AND OF HEL TRANSMITTER ARE COINCIDENT ON REGISTRATION SENSOR FOCAL PLANE.

SETTING ORIENTATION OF BACKSIDE ALIGNMENT MIRRORS

(Continued)

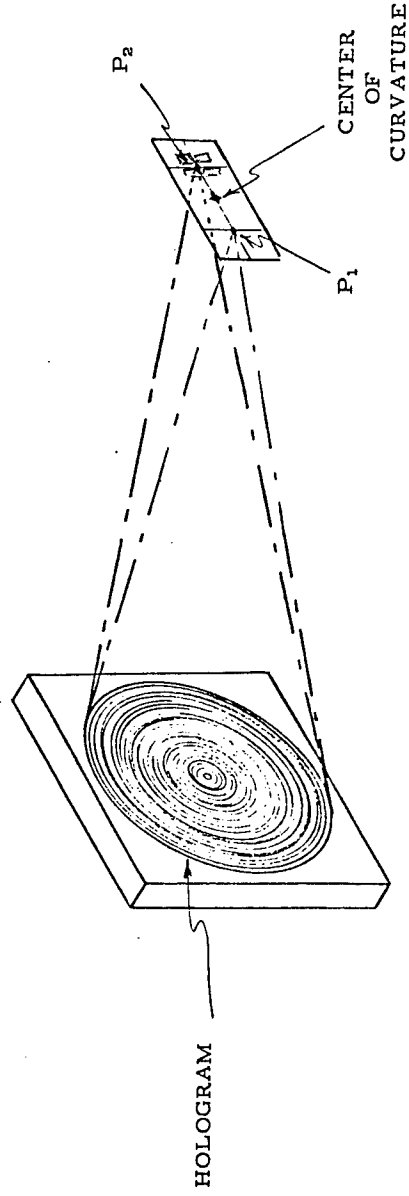
- ROTATE RELAY MIRROR (SEGMENT) ABOUT IT'S SURFACE NORMAL, USING RF LINK TO KEEP HEL BEAM DIRECTED AT GROUND RECEIVER. COINCIDENCE OF BEACON AND TRANSMITTER IMAGES WILL BE DISTURBED BY ROTATION.
- ADJUST BACKSIDE ALIGNMENT MIRRORS TILL IMAGE REGISTRATION IS NOT DISTURBED BY MIRROR ROTATION. THIS ASSURES FULL ALIGNMENT.
- WE NEED TO BE ABLE TO ASSURE THE MAINTENANCE OF THIS ALIGNMENT WHEN THE RELAY MIRROR IS POINTED IN ANOTHER DIRECTION.

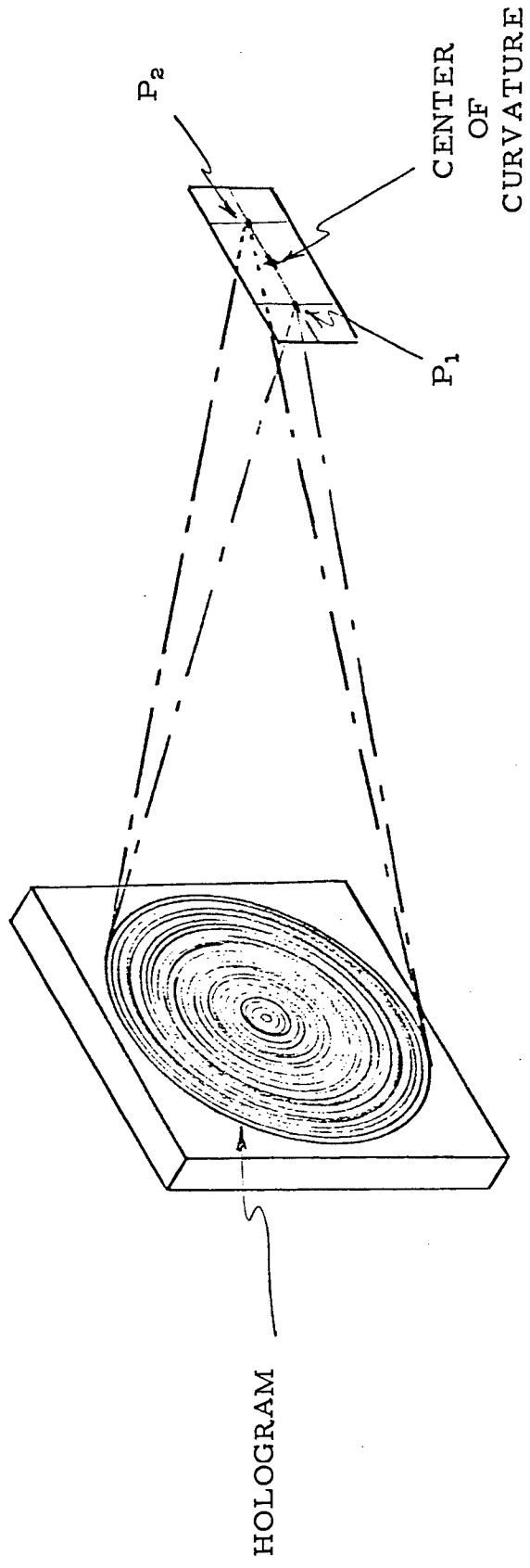
HOLOGRAM CHARACTERISTICS

- A HOLOGRAPHIC "LENS" IS AN OPTICAL ELEMENT WHOSE POSITION/ ORIENTATION IS ABSOLUTELY FIXED WITH RESPECT TO ITS SUBSTRATE.
- THE SUBSTRATE CAN BE AN OPTICAL ELEMENT ITSELF, SUCH AS A FLAT MIRROR.
- BUT THE SUBSTRATE NEED NOT BE AN OPTICAL SURFACE. IT COULD BE THE UNFINISHED BACK OF A MIRROR.
- THE HOLOGRAPHIC "LENS" CAN COVER THE ENTIRE SURFACE OF AN OPTICAL ELEMENT WITHOUT SIGNIFICANTLY INTERFERING WITH THE ELEMENT'S BASIC PERFORMANCE. (LOW EFFICIENCY HOLOGRAM)
- MULTIPLE HOLOGRAPHIC "LENSES" CAN BE PLACED ON TOP OF EACH OTHER.

SPHERICAL MIRROR HOLOGRAM

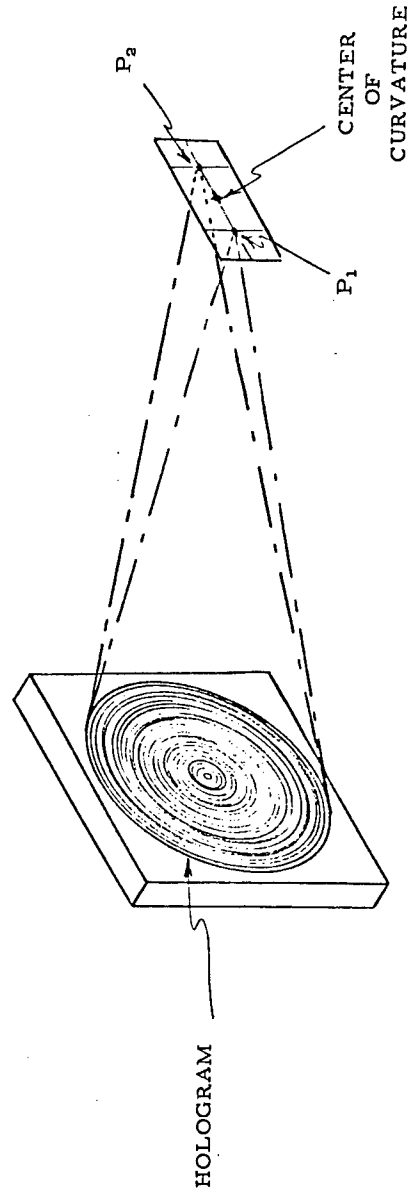
- WE ARE INTERESTED IN "SPHERICAL MIRROR" HOLOGRAMS WHICH IMAGE A POINT ONTO ANOTHER NEARBY POINT --- A HOLOGRAM FORMED BY THE INTERFERENCE BETWEEN TWO NEARBY POINT SOURCES.
- THE MIDPOINT BETWEEN THE TWO POINT SOURCES IS THE CENTER-OF-CURVATURE OF THE "SPHERICAL MIRROR" HOLOGRAM.

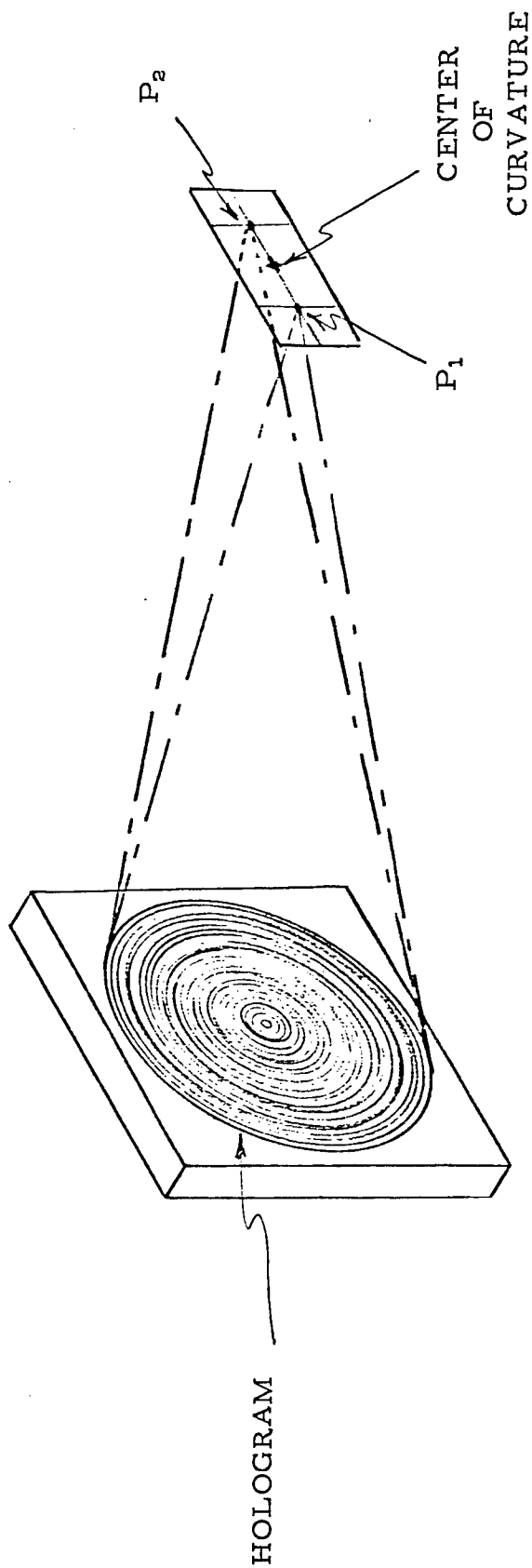




SENSING LOCATION OF CENTER-OF-CURVATURE

- PLACE A PIN-HOLE AT P_1 WITH COHERENT, DIRECTIONAL ILLUMINATION BEHIND IT. (RADIATED ILLUMINATION PATTERN WILL JUST FILL HOLOGRAM.)
- PLACE DETECTOR ARRAY AT P_2 ON VERY LIMITED STROKE FOCUS DRIVE.
- ILLUMINATE HOLOGRAM, ADJUST DETECTOR ARRAY'S FOCUS, AND DETERMINE POSITION OF HOLOGRAPHIC IMAGE OF PIN-HOLE.
- CENTER-OF-CURVATURE IS HALF-WAY BETWEEN PIN-HOLE AND IMAGE OF PIN-HOLE.





RELATIVE ORIENTATION STABILIZATION

- PLACE THREE CENTER-OF-CURVATURE SENSORS FAR APART ON A DIMENSIONALLY STABLE "REFERENCE" OBJECT.
- FORM THREE HOLOGRAMS ON THE OBJECT OF INTEREST, WITH THEIR CENTERS-OF-CURVATURE SPACED ABOUT THE SAME AS THE SPACING OF THE THREE SENSORS.
- POSITION THE OBJECT OF INTEREST WITH RESPECT TO THE REFERENCE OBJECT AND DETERMINE THE LOCATION (RELATIVE TO THE REFERENCE OBJECT) OF THE THREE CENTERS-OF-CURVATURE.
- CLOSE A KALMAN FILTER SERVO LOOP WHICH WILL HOLD THE LOCATION OF EACH OF THE THREE CENTERS-OF-CURVATURE CONSTANT.
- THIS WILL HOLD THE ORIENTATION OFF THE OBJECT OF INTEREST STABLE WITH RESPECT TO THE REFERENCE OBJECT.

ORIENTATION STABILIZATION OF MULTIPLE OBJECTS OF INTEREST

- WITH DIRECTABLE ILLUMINATION FROM THE PIN-HOLE A CENTER-OF-CURVATURE SENSOR CAN SUCCESSIVELY DETERMINE THE LOCATION OF THE CENTER-OF-CURVATURE OF HOLOGRAMS LOCATED ON DIFFERENT OBJECTS OF INTEREST.
- BY TIME SHARING EACH OF THE THREE CENTER-OF-CURVATURE SENSORS ON A REFERENCE OBJECT, THE ORIENTATION OF A MULTIPLICITY OF OBJECTS OF INTEREST CAN EACH BE STABILIZED WITH RESPECT TO THE REFERENCE OBJECT.
- IF THE ORIENTATION OF TWO OBJECTS ARE EACH STABLE WITH RESPECT TO A THIRD, THEN THE TWO OBJECTS HAVE STABLE ORIENTATION WITH RESPECT TO EACH OTHER.

MAINTAINING ORIENTATION OF BACKSIDE ALIGNMENT MIRRORS

- THREE OBJECTS OF INTEREST—TWO BACKSIDE ALIGNMENT MIRRORS, AND THE RELAY MIRROR (SEGMENT) AS SEEN FROM THE BACK. EACH HAS THREE SPHERICAL MIRROR HOLOGRAMS ON IT—A TOTAL OF NINE CENTERS-OF-CURVATURE.
- USING THE GROUND STATION RF LINK, THE THREE OBJECTS OF INTEREST ARE ADJUSTED TO THE DESIRED ORIENTATION WITH RESPECT TO EACH OTHER, I. E., MUTUAL PERPENDICULARITY.
- WITH THE GROUND STATION CONTROL STILL IN EFFECT THE LOCATION OF ALL NINE CENTERS-OF-CURVATURE IS DETERMINED WITH THE THREE CENTER-OF-CURVATURE SENSORS ON A REFERENCE OBJECT.
- THEREAFTER, CLOSING KALMAN FILTER SERVO LOOPS ON THE CENTER-OF-CURVATURE SENSOR DATA, THE THREE OBJECTS OF INTEREST ARE HELD STABLE WITH RESPECT TO THE REFERENCE OBJECT AND IN STABLE ORIENTATION WITH RESPECT TO EACH OTHER.

RECOMMENDED TECHNOLOGY PROGRAM FOR MONOCLE POINTING SENSOR

- THE LONG POLE IN THE TENT APPEARS TO BE THE HOLOGRAM CENTER-OF-CURVATURE SENSING TECHIQUE FOR MAINTAINING THE ORIENTATION OF THE BACKSIDE ALIGNMENT MIRRORS.

- PROGRAM SHOULD CONSIST OF

- ANALYSIS

- * SENSITIVITY FACTORS
- * SECOND ORDER EFFECTS

- LABORATORY DEMONSTRATION

- * CENTER OF CURVATURE SENSOR
- * STABILIZATION OF SINGLE OBJECT OF INTEREST RELATIVE TO A REFERENCE OBJECT
- * TIME SHARED SENSORS, STABILIZATION OF THREE OBJECTS IN A CORNER PATTERN.

- ESTIMATED TECHNOLOGY PROGRAM SIZE

- TWO YEARS

- ≈ \$225,000/YEAR

150 - 82
225 - 83
75 - 84
2 1/2 year total = 450