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PROGRESS REPORT

December 15, 1959 to January 15, 1960

Submitted by: STAT

SUMMARY

OPTICAL SYSTEM

An optical system, a modified Schmidt in form, has been evolved which provides a flat focal plane. This is a great assistance in reducing the problems of the film transport and IMC. In addition it may permit a 24" focal length.

WINDOWS

Analyses of available Bureau of Standards data has led us to the use of 3000 lbs. per square inch as the allowable fiber stress. Two blanks, one 16" in diameter from Heraeus and one 30½" in diameter from Corning, have been received and are being polished so that they may be inspected for optical quality. A thermal shutter in the window appears to be quite effective in limiting the heat flux into the bay. The feasibility of such a shutter will be determined by design study.

CAMERA STEADINESS

A mock-up of the stabilization system is under construction and will very shortly be available for tests. While this mock-up will use gyros at hand, two gyros of more recent design offer promise of considerable improvement and will be added to the mock-up as they become available. A preliminary design for aircraft attitude simulator is complete and specifications have been released for quotation.

MECHANICAL COMPONENTS

Mock-ups of film transport, concentric spools and turning rollers are under construction.

SUMMARY (Cont'd)

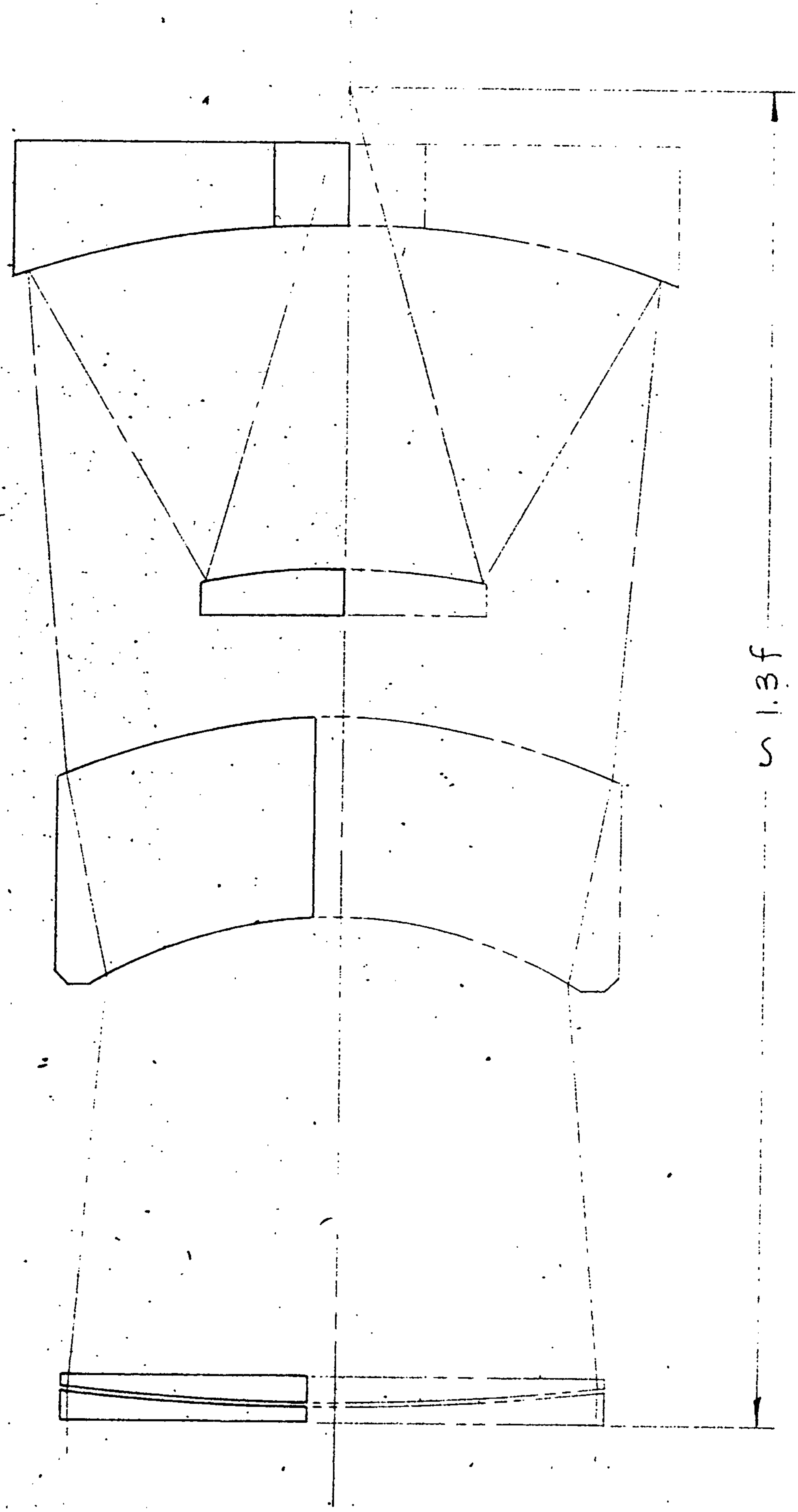
TEST FACILITIES

A small vacuum chamber for evaluating the optical effect of the bay environment is under construction and very nearly completed. A much larger test chamber to receive the entire configuration has been specified and released for vendor quotation.

OPTICAL SYSTEM

To date two optical systems have received the most attention. One of these, designated as the Flugge system, characterized by narrow field, has rather serious problems of image size and, thus, low resolution at the larger field angles. This has influenced us to give preference to a Schmidt system, which produces excellent images but suffers from two major disadvantages: First, it requires a curved focal plane and, second, its overall length is two focal lengths and, therefore, for desirable field angles, this system requires rather sizeable and thus heavy optics. Something over a month ago, a suggestion by Dr. Baker appeared promising in that it provided a very much smaller system having given focal length and thus, for our use, would permit a longer focal length within the size and weight limitations. In addition, a basic property of the new system would be a flat focal plane. In the period covered by this report, the basic system and several varieties have been investigated in an attempt to discover its true image forming capabilities. The images were disappointingly large at field angles required by a useful application of the system. During the same period, a complete analysis of the image motion compensation requirement for any system having spherical focal plane was carried out. It develops that such systems produce uncompensatible image motions for field angles as large as are necessary in our application. This results directly from the fact that the velocity of motion is a function of field angle and, therefore, the film or the image must move at different velocities at different points simultaneously.

Three additional lens systems have been examined: one is the previous Schmidt system with a field flattening lens. Images from this system are quite unsatisfactory. Second, is a modification of the Schmidt system in which the


~ 1.3 f

field is flattened by an additional curved mirror. This basic system has proved extremely satisfactory in a large astronomical telescope and has been carried through a rather complete design for a 12" f/2 photographic lens. Our analysis indicates that an 18" f/4 segment of a f/2 system with a field of 14° would produce satisfactory images. At this writing, further design investigations are being carried out for a 24" f/3.5 system covering a 20° field. The increase in focal length is possible because of the magnification of the secondary mirror which makes this overall system about 1-1/3 focal lengths long rather than the two focal lengths of the classical Schmidt. If the images of faster, wider field, longer focal length system are satisfactory, the change in the layouts submitted to date is quite minor in that one of the flat mirrors is replaced by a convex mirror. All other components are changed in detail, but not in general size or location. Additional study has been made of the choice of coverage with and without stereo and a table is included to show some of the alternatives.

The third system is a nearly classical Petzval with its attendant disadvantage of strong variation of focal length with temperature and pressure. A design already carried out for another problem was examined in a form suitable for our use. Again, the images at our required field angles were not acceptably small.

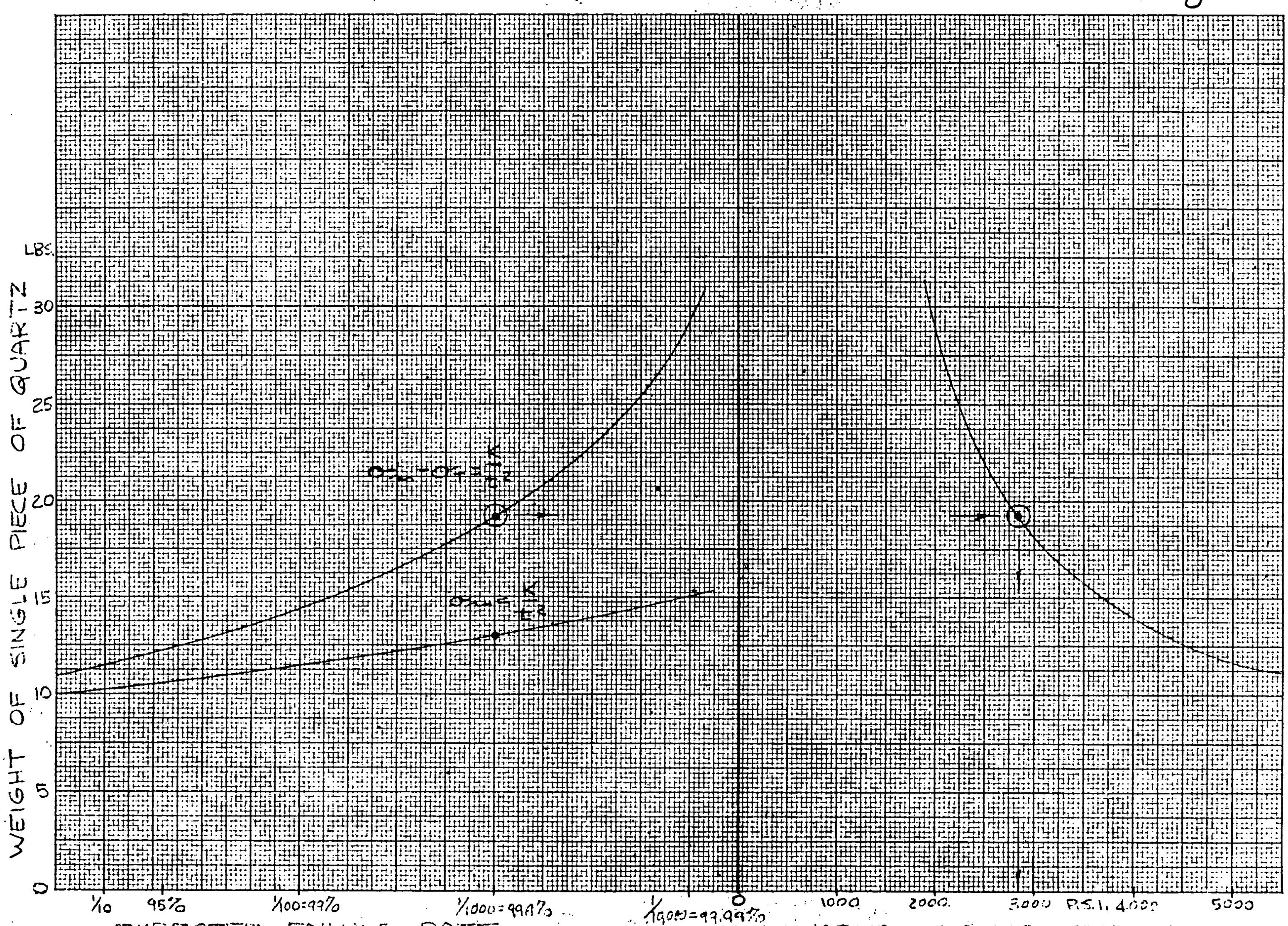
CASE	ASSUMED				RESULTS		
	EFL	RANGE	FILM LENGTH	COMPLETE STERO	FIELD ANGLE	FILM WIDTH	FILM WEIGHT
1	24"	2500	4500	YES	30°	13"	117#
2	24"	2500	6100	YES	21°	9"	110#
3	18"	2500	4500	YES	21°	6.8"	61#
4	18"	2500	6300	YES	15°	4.8"	61#
5	18"	2500	4500	(10 MILE STEREO)	11°	3.5"	32#
6	12"	2500	4500	YES	14°	3"	27#
7	24"	2500	4500	(10 MILE STEREO)	14°	6"	54#
8	24"	1800	4500	YES	21°	9"	81#
9	24"	1000 1500	4500	YES (10 MILE STEREO)	20°	9"	81#
10	18"	1000 1500	4500	YES (10 MILE STEREO)	14°	4.5"	41#

WINDOWS

As background information we have looked into the simplest possible window area consisting of two layers, the outer one necessarily of quartz and whose inner surface is at 500°F. The upper window might be of optical glass since we have assumed that its temperature is 120°. Both inner surfaces are coated with a reflecting film whose emissivity in the infrared is two-tenths but which is quite transparent in the visible. The space between the glassex is to be evacuated. This window configuration produces a heat flux for windows of the size we are now contemplating of 160 watts. This heat must be removed by the atmosphere of the bay. It is our feeling that this heat flux is much too great to be handled by a simple convection cooling at the upper surface. In order that we may be able to obtain direct data on the optical effects of convection over the range of pressures from atmospheric to ambient in the bay and over a wide range of temperature differentials between the upper surface of the window and the bay environment, we are building a box which can be heated and evacuated to simulate this portion of the optical path. Most of the components of this experiment are at hand and tests will start January 22nd. It is hoped that early results from these tests will give us a sound foundation for specifying the environment and permissible heat input from the windows to the bay.

The National Bureau of Standards during 1958 ran a large number of tests on a variety of optical materials at elevated temperatures to determine the breaking stresses for slowly applied forces. Among the materials tested was quartz so this data has been analyzed. The results showed a wide range of fiber stresses at failure depending strongly on the surface condition of the samples. Some of the polished plates failed at fiber stresses considerably below the average for all plates even though there were no detectable

FROM N.B.S. DATA REPORT NO. 6582 DATE DEC. 1958



flaws in the surface. It was found that by sandblasting the surface under carefully controlled conditions, the spread of failure stresses could be greatly reduced. The average stress now was located at the point where the weakest polished specimens previously failed. Since the flaws in the polished specimens could not be detected, it was felt that these abraded samples might be a better measure of the likelihood of failure in the sort of operation we are contemplating. The distribution of stresses at failure from the National Bureau of Standards data was used to predict the reliability percentages as a function of stress. The fiber stress for windows of various thicknesses and, therefore, various weights, was computed and compared with the predicted reliability from the test data. The stress employed for these computations was the sum of that due to one atmosphere on the plate and that due to thermal stress produced by temperature gradients in the plate deduced from the analog computer data when combined with the temperature profile for the mission. This latter stress reaches 1000 psi a few minutes after take-off during climb-out, but eventually stabilizes at a nearly negligible value during the rest of the flight. From the shape of the curve, we concluded that to aim for reliability greater than 99.9% or one failure in a thousand, resulted in a considerable weight penalty. On the other hand, the cost in weight for a reliability of 99.9% as compared to 99% was rather small. We, therefore, recommend the use of 3000lbs. per square inch as the design fiber stress since this number corresponds to the 99.9% reliability value. This number does not include the normal 1.5 designing factor of safety. It would be my suggestion that a window test procedure producing thermal stresses and mechanical stresses exceeding those realized in operation by a factor of 1½, would permit a design stress of 3000 psi.

We are preparing a test program which would involve a request to the Bureau of Standards to repeat the type of tests already performed, but on BK-7 glass. It now appears possible to utilize this glass in the second and third layers rather than the much more expensive quartz, provided thermal shock tests indicate its usability. The basic designs for mounting these pieces of glass have been prepared and are serving as a basis of discussion with material consultants, vehicle manufacturer, and others.

Following the suggestion of Dr. Purcell, the effectiveness of a thermal shutter has been determined. It appears that the thermal flux through the window can be reduced by at least a factor of two with a properly designed shutter. A feasibility design study is under way so that the problems of providing such a shutter in the restricted surface and high vacuum environment may be properly evaluated. One undesirable aspect of the shutter has come to light and that is that the heat flux comes in pulses in the second window and this may produce undesirable optical effects.

We have received samples of large discs of fused silica; one 16" in diameter from Heraeus, and one 30½" in diameter from Corning. These samples are now in our Optical Shop being polished so that they may be inspected for optical homogeneity.

However the windows are constructed, all of our current thinking depends on the availability of satisfactory coatings. These coatings should be low emissivity but higher reflectivity in the infrared as well as high transmission in the visible. We have received some encouraging information from the coating industry concerning not only improvements in the present gold coating technique, but other methods of inducing high transmission in the optical region in otherwise high reflecting metallic coats.

CAMERA STEADINESS

The aspect of this portion of the program which has received the greatest attention during the last month has been the planning of the stabilization method. In order to realize our objectives, a gyro with a noise level at its null of the order of 1/10 of a second of arc when filtered to a time constant of 1/100 of a second is required. A Minneapolis-Honeywell gyro, GG87, which is of the HIG form, but miniaturized, seems to have the necessary characteristics. One disadvantage of this gyro arises from the fact that its basic action depends on the viscosity of the fluid with which it is filled--very accurate temperature control is required. In its normal form, considerable heat input for the thermostats must be available. While it is possible to arrange other methods of thermostating, since this heat input is objectionable, the details are yet to be established. An attractive alternative is a gyroscope of new design developed by Sperry which has the advantages of great sensitivity and reliability and a considerably lower noise level at null. A single gyro will provide signals about two-axes and, therefore, the system would be quite a bit smaller overall. It may not be possible to obtain prototypes and produce units of this more attractive unit on the schedule which must be maintained on this project. A mock-up of the stabilization system is under construction which will duplicate the moment of inertia of the camera. Readily available HIG-5 gyros are to be used in the mock-up and tests will start on February 5th. The first stabilization form to be investigated would employ reaction flywheels of such size as to represent about 1% of the moment of inertia of the camera. This system will also include the weight shifters to provide 50 in.-lbs. of gravitational torque.

MECHANICAL COMPONENTS AND ASSEMBLIES

A mock-up of the film transport mechanism, including IMC devices and film velocity control mechanisms, has been laid out. This mock-up is expected to be in operation March 15th. A prototype of the coaxial spool arrangement will be ready for test early in February and since this device requires a film turning roller, several alternate mechanisms have been assembled. An air floatation psuedo roller is yielding excellent results and will be the subject of further detailed investigation. A large sliding sector roller as an alternative was given some study some time ago but will need to be greatly reduced in size and weight before it becomes attractive. The beaded roller scheme, used in the E-2 camera for this purpose, we are told by the Air Force, has proved completely satisfactory but we wish to obtain further data on the tendency of this roller to pressure mark the film.

ELECTRONICS

During the past month design work on the V/H sensor has continued and a variety of solid state detectors have been studied to determine which would be the most suitable for this specific problem. The electronics required for the mock-up of the stabilization mechanism are 70% completed. Studies of the servo requirements for film velocity and mirror rotation velocity control continue.

TEST FACILITIES

Specifications for a three-axes attitude simulator capable of supporting the whole configuration have been prepared and some manufacturing quotations solicited. This simulator will provide optical methods of checking the methods of stabilization of equipment of the configuration under carefully controlled conditions of angular motion about the three axes. In addition to the small vacuum chamber for optical tests of the bay environment mentioned above, a large chamber capable of receiving the entire configuration and providing the thermal and pressure environment to be expected from the bay, has been specified. These specifications have been released to interested vendors and some quotes received. It has been our policy to attempt to get work on these test facilities under way early enough so that they will be ready for use by the time the equipment is ready for test.

	COMPONENT OR SUBSYSTEM / CATEGORY		WEIGHT (POUNDS) GLASS A	FILM B	STRUCTURAL FRAME C	COVERS D	CONTAINERS E	BAFFLES F	ELECTRONICS (INCL. WIRING) G	MOTORS SYNC H	SOLENOIDS I	PUMPS J	CONNECTING RODS K	SHAFTS L	ROLLERS & SKID M	BEARINGS N	VALVES O	COOLANTS P	TUBING Q	BRAKES OR CLUTCHES R	GEARING S	LINKAGE T	LENS CELL U	MISCELLANEOUS ITEM	MISCELLANEOUS WEIGHT	TOTAL WEIGHT (POUNDS) DESIGN ESTIM.	TOTAL WEIGHT DETAIL DWG	TOTAL WEIGHT ACTUAL	HEAT DISSIPATION TOTAL WATTS	POWER CONSUMPTION TOTAL WATTS	TOTAL CONCEPT WEIGHT (LBS)
1	OPTICAL SYSTEM (INCL. SCANNING & LIGHT BAFFLING) SEE ITEM # 19	DESIGN ESTIM.	95	0	20	0	0	1		1	0						0		0			1	15			133					
		DETAIL DWG																													
		ACTUAL																													
2	GIMBAL SUPPORT (IN ITEM # 7)	DESIGN ESTIM.																													
		DETAIL DWG																													
		ACTUAL																													
3	V/H SENSOR	DESIGN ESTIM.																								5				10	5
		DETAIL DWG																													
		ACTUAL																													
4	IMC SYSTEM	DESIGN ESTIM.	0	0				0	4	2								0								6				20	
		DETAIL DWG																													
		ACTUAL																													
5	AUTOFOCUS SYSTEM	DESIGN ESTIM.																													
		DETAIL DWG																													
		ACTUAL																													
6	EXPOSURE PROGRAMMER	DESIGN ESTIM.																				2				2				10	
		DETAIL DWG																													
		ACTUAL																													
7	STABILIZATION	DESIGN ESTIM.							83																	180				300	180
		DETAIL DWG																													
		ACTUAL																													
8	MAIN STRUCTURE	DESIGN ESTIM.																													
		DETAIL DWG																													
		ACTUAL																													
9	AUTOBALANCE (IN ITEM #7)	DESIGN ESTIM.																													
		DETAIL DWG																													
		ACTUAL																													
10	CAGING (IN ITEM #7)	DESIGN ESTIM.																													
		DETAIL DWG																													
		ACTUAL																													
11	FILM TRANSPORT	DESIGN ESTIM.		60	18		20		4	8				4	13	2				1	7					137				80	
		DETAIL DWG																													
		ACTUAL																													
12	SHUTTERING	DESIGN ESTIM.								1				2												3					
		DETAIL DWG																													
		ACTUAL																													
13	POWER CONTROL & REGULATOR	DESIGN ESTIM.					2		20																	22				60	
		DETAIL DWG																													
		ACTUAL																													
14	OPERATOR CONTROL	DESIGN ESTIM.				1	2		2																	5				10	
		DETAIL DWG																													
		ACTUAL																													
15	PROGRAMMER	DESIGN ESTIM.					2		10																	12				30	
		DETAIL DWG																													
		ACTUAL																													
16	ANTI-STATIC	DESIGN ESTIM.							5																	5					
		DETAIL DWG																													
		ACTUAL																													
17	DATA PRESENTATION	DESIGN ESTIM.	.5						1.5																	2				10	
		DETAIL DWG																													
		ACTUAL																													
18	POSITIONING	DESIGN ESTIM.							3																	3				40	
		DETAIL DWG																													
		ACTUAL																													
19	SCAN SERVO DRIVE	DESIGN ESTIM.																								5				10	5
		DETAIL DWG																													
20	VIBRATION ISOLATORS (EXTERNAL) 10% of TOTAL SUPPORTED WEIGHT	DESIGN ESTIM.																								10					10
		DETAIL DWG																													
		ACTUAL																													
21	PLATEN CONFIGURATION WITH IMC	DESIGN ESTIM.			4					2											8	2				16				20	
		DETAIL DWG																													
		ACTUAL																													
22	COOLING	DESIGN ESTIM.																								20					20
		DETAIL DWG																													
		ACTUAL																													
23		DESIGN ESTIM.																													
		DETAIL DWG																													
		ACTUAL																													
24																															
25																															
26																															
	SYSTEM TOTAL	DESIGN ESTIM.																								566			540	600	
		DETAIL DWG																													
		ACTUAL																													
	WINDOW	DESIGN ESTIM.																													
		DETAIL DWG																													
		ACTUAL																													