From: Ir. MSc. C.G.M. van ‘t Klooster Voorhout, 27 Sept 2018

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- Available for monitoring activities,

ROT 54/2.6

This report presents observations made with pictures explaining a status. There is a main issue to be repaired and carefully inspected (cardan suspension of assembly carrying optical telescope and sub-reflector). Its feasibility of repair is a very important task to be realized as soon as possible. Only then the sub-sequent tasks can be carried out, like new cabling, control and calibration of angular control. This report describes the importance of the repair in the contaxt of the telescope status.

The details provided about ROT 54 are in the attachment. Many more observations and pictures are available. The main observation related to the cardan suspension is important here.

The radio-telescope exploits a fixed spherical mirror and a secondary mirror, which is dimensioned such that a secondary focus is created in a location in which a radio frequency feed is mounted.

The secondary mirror assembly with its supporting structure and 3 struts has a weight of **130 ton.** The turning structure consists of the sub-reflector (**15 ton**) and total counterweight (**12 ton + 6 ton** for the optical telescope and additional counterweight respectively). The cardan bearing is **20 ton** mounted on top of 3 supporting struts of each **12 ton**. The struts are not straight but curved. This is beneficial for the allowable angular range. It has an electromagnetic benefit as well: the diffraction of the plane wave is spread out and does not form diffraction cones as severe as would be the case for a straight support.

Mass figures are broken down, but it requires a verification. It is clear that there is a loading on the axes in the cardan suspension, which is heavy. It must be precise as it determines pointing of the beam.

Fig.1 View from Nord towards South with the church in village “Teger” on the Nord-South line.

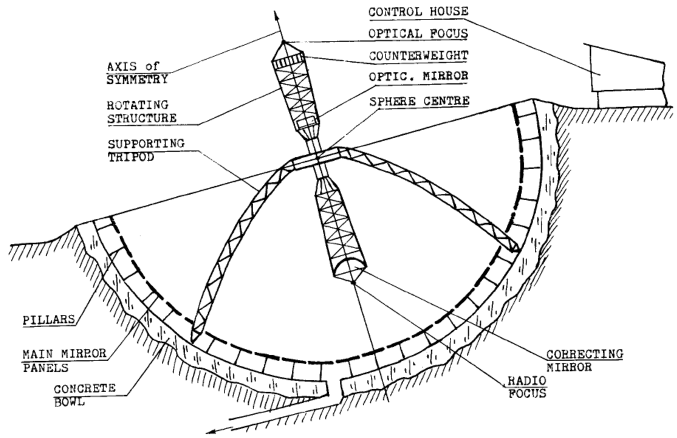

Figure 3 Arrangment of Radio-Optical Telescope ROT-32/54/2.6

Fig.2 Schematic view East - West (ICAP 1989, P.M. Herouni "The First Radio Optical Telescope"),

The counter-ballast is usefully exploited with an optical telescope pointing into the same direction as the radio beam. It realized the first radio-optical telescope, explaining the short notation ROT 54/2.6 for the diameters of the main radio spherical mirror and the optical telescope mirror.

A particular important, main property of the spherical reflector is that it is fixed in the ground. No need for "a homologous designs" or "Finite Element Method" optimization for an accurate and light supporting construction as for a steerable main reflector. The main spherical reflector has a surface error which follows from a budget comprising mainly the error in the installation of the panels and the actual panel surface errors. The latter main reflector surface error **is not subject** to any deviation during a pointing operation of the radio telescope in principle.

The Main Spherical Reflector and Panel Configuration

The main-mirror is mounted on concrete, fixed in the ground (**Fig.2)**. The radio optical telescope ROT 54/2.6 has a 54 m non-movable spherical reflector, consisting of some 3800 panels of ca 1 by 1 meter (3700 m^2 = 2pi r^2 for a half-sphere → 4580 m^2 for R=27m): some panels are larger. Panel mounting is on 4 tuning screws: panel errors at the rim are larger by a ratio (panel size)/(screw separation).

All panels are made of aluminum-magnesium-zinc alloy. Eventually the absorption and emission coefficients for such material is needed in a thermal distortion analysis to assess gradients in temperatures, but this is for later. Steel mounting rods and panels are assumed to be well thermally conductive.

Panels are milled towards a spherical shape with a final error at panel level of ±10µ. With a radius of 27 meter and a panel sizing of 1 by 1 meter, the deviation of a flat panel from a spherically milled panel is 27000000*(1-cos(η)), with η=1/54 (1/2m at 27 m, assuming a 1by1 m panel) or about 4.63 millimeter.

With 180 panels in the upper rings there is an adaptation with such machining to circular shape. If it was a flat panel, the periodic deviation would equal 4.63/2 mm = 2.3 mm peak-peak across the panel and ~sqrt(2) more in diagonal sense. It would be ε= 2.3/(sqrt(3))=1.328mm across. (If we assume a uniform error distribution for convenience). It is a good first estimate order for rms, to be refined.

For a minimum wavelength λ_{min} = 20 * 1.328 it results that such a reflector would still be reasonably good at X-band (one could have used flat panels up to ~ X-band or 30 mmm wavelength), provided the panels are "perfectly mounted" perpendicular to the radius of main reflector. It shows perspective for higher bands !! In other words, a panel surface accuracy might be no issue below X-band, but the panel setting accuracy in terms of "rms" should not exceed a smaller value. How much? It depends.

The error in the panel setting can be much smaller obviously, given a systematic required spherically shaped panel surface. Accordingly the reflector would allow operation up to millimeter wave regime.

Given a secondary mirror of ~5 meter diameter and about ~±60° subtended angle, a small feed would be needed at centimeter wavelength below X-band (no allowance for a long feed-horn) resulting into a secondary pattern with a higher first side-lobe due to a predominant main aperture distribution with its maximum shifting towards the outer radius →relative high first side-lobe near to – 10 a -15 dB. At low frequency accommodation has to be complied with.

The panels have been precision milled with ±10 µ rms on a carousel-milling machine. All separate panels are mounted on a metal tube which is anchored into the concrete below the spherical main reflector. The distance between the 4 bolts is approximately 30 centimeter. Accordingly an error in the setting of a bolt of ±15µ would be magnified by a factor 2 to 3 at the panel edge to say ~±45µ.

Accordingly an estimate can be made for a total rms surface error for the spherical mirror

Fig.3 Panel mounting, Average gap width between panels indicated as 2 mm.

A very suggestive observation is made from the reflection of the Sun into the reflector. Panels are machined in a systematic manner leaving observable rings on the panel surface. The sun reflection observed over a number of panels is indicative for a reasonable good panel setting, because of the regularity of the characteristic sun reflection over more panels, caused by the separate panels and additionally a diffraction behavior in the optical domain due to circular rings observed at panel level (manufacturing process). An example is shown in Fig. 4. Slightly tilted panels could be found in this way.

Fig. 4 The Sun reflected from spherical mirror.

An Indicative regular pattern from panel to panel results with a small white band on each panel. The orientation of such band varies gradually from panel to panel and is a reasonable indication that even today the panel setting might well be acceptable for operation in the centimeter wavelength regime. Displacement of the bright location varies over time due to Sun movement or by walking around the main reflector rim…

Obviously a refined measurement approach has to confirm precise details, with a laser in the center of the half-sphere.

Fig.4 shows also the small platform on which the RF feed assembly has to be mounted.

Clearly the access to the RF front-end is a situation to be taken into account, when considering the illumination of the secondary reflector. One should not go too much below 5 GHz, possibly 3 GHz (λ=10 cm), given the physical sizing of even low-gain RF-feeds and accommodation needed. Given such observations, the spherical mirror would be in **a reasonable status even today** for centimeter wavelength observations, with perspective for higher frequencies.

The sub reflector surface and secondary RF platform

The surface of the sub-reflector is shaped according to a precise required geometry (spherical aberration correction) and a location to be precise with respect to the main spherical reflector. The claim of inventing such correction has been made at the same time by Dr. P. M. Herouni and by specialists involved in the Arecibo reflector. With a perspective for utilization up into the millimeter wave regime, the ROT 54 radio telescope can be “electrically “ larger than the Arecibo antenna.

The RF feeding point has to be located accurately with respect to the sub-reflector geometry. Being a low-gain RF feeding point, not much deviation in the RF coordinates is allowed. It has to be within about ±0.1 a ±0.2 λ. This needs verification. It would be as a crude estimation ±3mm a ±6 mm in X-band. It is clearly more demanding in the millimeter wave regime. It demonstrates the criticality of a precise cardan suspension needed and bending aspects (already addressed in the book of P. Herouni) as function of pointing for higher frequencies. Resulting deviations can be decomposed into statistical and systematic deviations, to be entered in calibration tables. This is for future work.

The sub-reflector assembly and its revival of control capability

It is noted that the total mass of the tripod support and movable mass is 71 ton, resting on 3 positioners as strut support locations with a total of 130 ton with a major loading of the south strut due to the off-zenith direction of the main axis of symmetry.

Behavior of the beam direction due to systematic gravity influence

The movement of the secondary reflector provides a beam direction by putting it into a desired direction (θ-180)° for a main-beam into direction θ°, the angles measured with respect to the symmetry axis of the spherical reflector. The main symmetry axis is oriented towards a direction +25° to “South” leaving 15° with respect to the local zenith at 40°, the latitude of the location of the telescope. A beam pointing is available from 35° elevation (“South”) to 85° elevation (“Nord”).

All pointing deviations are due to bending and pointing errors of the movable structure of the sub-reflector. Such errors are in part systematic and can be calibrated. Given the mass and length of the pendulum-like structure this will be important. Given the off-zenith symmetry and loading of the “South” support strut, there will be a systematic behavior in the calibration table for angular errors due to (linear) bending.

A useful area of 32 meter diameter is selected from the spherical reflector. With a secondary reflector correcting the spherical aberration an aperture of 32 meter with a blockage of ~6 meter diameter is available, to be illuminated by a spherical small feed over ~±α°, with α leaving a little bit illumination thus side-lobe control. Given the aperture blockage and α towards α=60°. Room for side-lobe control is limited an needs optimization (efficiency is high). The first side-lobe is ~-15 dB. The effect on the pattern has been investigated already (ICAP paper P. Herouni 1989) and particular choices of RF illuminating feeds are related obviously.

The RF front-end equipment

There has been no discussion about RF front-end equipment, neither IF and backend. This subject needs elaboration. Priority has been given to discussion of the main cardan suspension and its current status.

Reception of a simple but accurate and systematically known beacon signal for propagation measurements (narrow band CW) might be a very suitable way to assess a large number of error contributions and subsequent assessment of impact or improvement.

Reception of the Alfasat beacon at 19.7 GHz **and** 39.4 GHz could be a consideration at a later stage. Relevant background information about the propagation payload on Alfasat has been provided. Alfasat is positioned at 25° East in a slightly inclined orbit, thus virtually moving Nord-South daily over a couple of degrees.

A direct reception with a ROT 54 antenna pointed in a fixed position towards the satellite at 25° East would permit already 1 D pattern cuts, because the satellite is moving in a daily pattern (over ~ ±3°) in a systematic manner. Precise ephemeris data are provided on request (there are sometimes satellite control operations also). In this way a 1D (quasi) Nord-South pattern could be monitored, nicely related to predominantly one axis in the cardan system. It would require initial assessment and provision of RF reception capability for the CW signals. Alfasat propagation payload is available for some time more in the upcoming year and possibly after.

The CW carriers are rather stabile according to the information provided. Given a stabile 19.7 GHz CW signal, a direct reception by ROT 54 in comparison with a reception of the same signal with a much lower gain antenna can allow for holographic measurements. It would provide additional investigation capability and further fine tuning of the radio telescope.

Recapitulating

The spherical main reflector is in a very reasobale state, with perspective for further improvement

-a- The current status of the control of the sub-reflector and telescope assembly (movable part) is, that there is no control possible.

The main control room is out of order. Cables have been cut and it is likely that a new cabling is required. Control capability and associated cabling requires detailed assessment and repair.

-b- There has been no movement of the cardan suspension in the last 6 years.

-c- A main issue is, that one side of the East-West axis inside the cardan housing has a defect control arm.

This needs priority as without a repair there is no control of the East West axis possible. The current understanding is, that the lever for control of the angle of the latter axis is loose from the axis, with a bracket with broken bolts. How this has happened is unclear.

-d- A careful inspection is needed.

Just repairing the bracket alone is not a guarantee for a free and smooth and accurate movement of a secondary reflector assembly (with telescope included) and eventual control. The latter movement is required as the angular pointing of the RF-beam depends on that movement.

Only after inspection and repair of the bracket and careful mechanism investigation, linear actuators for moving the East-West axis (and Nord South axis) might again be considered for movement.

Obviously the control capability can only be considered after such a repair and (successful) inspection.

In summary:

As there has not been any movement in the last 6 years, a lubrication of moving parts is important and might not directly guarantee accurate movement, given a status of materials and movable parts.

Currently the East-West axis is blocked on purpose with welded brackets. It must be inspected the exact status of the mechanical parts within the cardan suspension, which carried the large mass of more than ~ 30 ton with two perpendicular axes and a central controllable tube to which on one side the sub-reflector assembly is mounted and on the other side the optical telescope.

The importance of the latter is also understood from the main criticality of positioning the sub-reflector with RF-plateau accurately within limits. The stability of the positioning has to be within limits dictated by the allowable error in the directivity.

The latter positioning error is more critical if a stabile phase behavior has to be realized over an angular interval of movement, as could be the case for a tracking of a radio source in a VLBI observation. Such phase deviation if any should be calibrated out for a major part by using calibration tables, based on systematic deviations.

The major ball-bearings have to be inspected.

The major control capability for the heavy sub-reflector + optical telescope is directly important and related to deviations in precision and is more demanding obviously at higher frequency bands.

Only after a repair of control bracket (west –side EW axis), inspection and preventive actions (lubrication ?) of all movable parts inside the cardan housing and attachment to struts, the behavior with angle can be derived in more detail.

Accordingly an initial operation might preferably be at longer wavelength, for instance in X-band, for which there is also experience in observations. Possibly the 19.7 GHz beacon of Alfasat is very interesting and permitting analyses of various error sources with subsequent fine-tuning.

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On request some details are given below

C.G.M. (Kees) van ‘t Klooster received an IR-degree in 1978 in Electrical Engineering from Eindhoven University and a MSc-degree in Space System Engineering in 2001 from Delft University. He is Lifetime IEEE Member and author or co-author in more than 150 papers.

In 1978 he joined Physics Laboratory TNO as antenna engineer with as topics ferrite phase shifters, waveguide based phased array antennas and planar near-field testing. In 1984 he joined European Space Agency (ESA-Estec) in the Technical Directorate covering subjects like antennas for satellite projects (remote sensing and scientific) including Meteosat, European Remote Sensing (ERS) and other satellites. He was responsible in ESA R+D contract studies on slotted waveguide antennas, feeds and feed-arrays, SAR- and radiometer antennas in early and later phases, antenna testing aspects and various activities on and advancement of large deployable antennas for radio astronomy, remote sensing and telecommunication. He was awarded ESA Douglash Marsh fellowship in 1993, which he spent in Moscow at Lebedev Physical Institute in Radio-Astron space-VLBI project team.

Achievements include initiation of dedicated new panel technology for ALMA with industry (Media-Lario) as a spin-off from X-ray telescope space technology and initiation of investigations with the institute JIVE into VLBI tracking of the Huygens probe during its landing on Titan. The work has been realised excellently by JIVE.

After retirement in 2015 he continues part time with antenna activities in universities and some consultancies.

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Attached: ROT 54 description with technical details as provided.

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Technical Certificate

on the Radio-optical Telescope ROT-54/2.6

Yerevan 2017

I. Introduction

Since 1971, under the leadership of Academician Paris Herouni, the creation of a complex of institutions has begun to work in Armenia in the field of radiophysical measurements, which, according to the author and the general designer, included the following necessary components:

1. **Aragats scientific centre** (in the neighbourhood of villages Orgov and Tegher in Aragatsotn Marz, mount Aragats),
2. **Centre for scientific-research and office activities in Yerevan**,
3. **Experimental plant Wave in Yerevan.**

In the scientific-production complex created by P. M. Herouni, scientific and technical research, as well as experimental and design works were carried out in the field of theory and technology of antennas, radio astronomy, space communication, telecommunication, communication systems, control systems, radio-measurements, and scientific-production facilities in the adjacent fields.

Under the leadership of P. M. Herouni, the scientists were awarded a number of high government awards (8 State Prizes of the USSR, 7 State Prizes of the Armenian SSR, medals and certificates). On the basis of scientific studies, 10 doctoral and 35 PhD dissertations have been defended, the Chair of Antenna Systems at Polytechnic University was formed, etc.

The above-mentioned components of the complex created by P. M. Herouni function under the jurisdiction of the National Institute of Metrology acting within the system of the Ministry of Economic Development and Investments.

At the Aragats Scientific Centre, a unique tool is located known in international scientific circles as a radio-optical telescope of Herouni **(ROT-54/2.6).** It is a large double-reflector antenna with a diameter of 54m combined with an optical telescope with a diameter of 2.6 m. Such a system is the first and unique in the world.

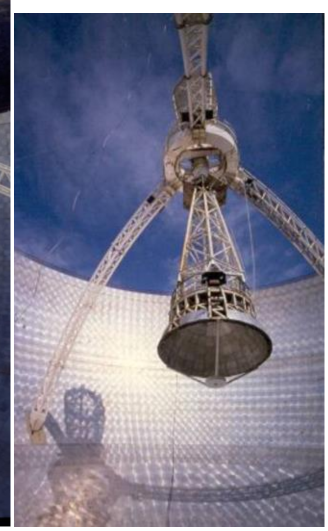
The Armenian antenna has a number of significant advantages over other large antennas in the world by a number of parameters. ROT-54/2.6 is applied in the space exploration and the deep space communications.

The design and construction of ROT-54/2.6 started in 1980. Since 1985, adjustment works on the antenna have started. In 1987, the radio telescope was commissioned. The radio-telescopes of this type are named "mirror radio-telescope of Herouni". The devastating earthquake of 1988 did not cause damage to the antenna structure.

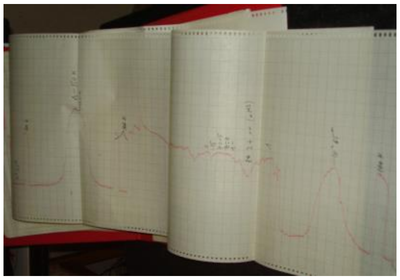
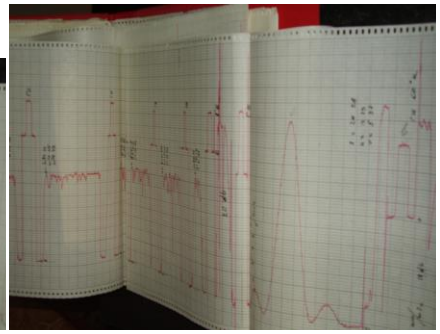
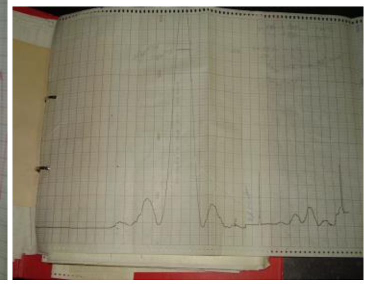
Advantages:

- **High accuracy,**
- **High sensitivity,**
- **Very low noise.**

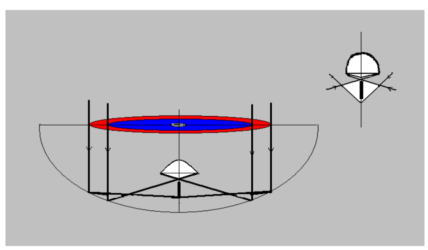




In the period of 1987-1990, under the supervision of Professor P. M. Herouni, planned observations were conducted, an outbreak of the red giant (the star η in the constellation Gemini) was recorded, numerous articles were published in the scientific periodicals of the USSR and abroad, and reports at conferences were presented.

Under the conditions of energy crisis of 1990-1995, a group of young scientists and students under the leadership of the Candidate of Technical Sciences, Associate Professor A. S. Sargsyan, carried out numerous measurements of the radio-telescope antenna by the radio astronomy method, recorded a new, unknown sources of radio emission in space, as well as made observations of Uranus and Jupiter with the optical telescope.


In the period of 1995-2001, the control system of the radio telescope was dismantled and replaced by more modern computers, a software product was prepared, joint projects with the Russian Astronomical Union were done, a research on prospective development of the radio telescope was conducted by the Athens Technological University, the stock of the feeds of the radio telescope antenna were updated and improved, as well as one PhD and more than ten Master theses and Bachelor diploma works have been defended on the subject.

In 2001-2010, in the frames of the basic grants for maintaining the Aragats Scientific Centre, preventive activities were carried out including lubrication of movable mechanisms, painting of metal structures, repair of the roof of the control panel building, etc. A model of a new radio-electronic system for controlling the antenna movement was developed. On the subject of the feeding systems of the antenna, another PhD thesis was defended. From year to year, the targeted state budget support contributed to the preventive works to preserve the antenna and repair the infrastructure. In the last five years of the mentioned period, some sections of the supply cables of the automatic control system of the antenna movement were dismantled and several circuit boards disappeared. However, the radio telescope is in good condition and can serve its purpose.

The theoretical and experimental studies on the antenna (mainly, measuring the antenna parameters, and in small amounts – radio-astronomical observations) during the past 25 years have been carried out under the conditions of very limited funding, mainly due to the enthusiasm of scientists and the staff.

In 2013-2015, after reforming the scientific-technical institutions in the system of the RA Ministry of Economy, once under the jurisdiction of National Institute of Metrology (NIM), the unique tool ROT-54/2.6 was not used as intended.

According to the resolution of the NIM authorities, the antenna ROT-54/2.6 is removed from operation because of the lack of financial means (Decision 01-11 of November Session of the NIM Scientific Board, 2012). Thus, in fact, the tool is not funded from the state budget.

The conclusion of the working committee created by the Chairman of the State Committee on Science of the RA MoES, in accordance with the order of the RA President (March 15, 2015) states: "To allocate funds from the state budget ... for the operation of the ROT-54/2.6 ... is not possible". It is proposed: "to attract foreign partners, international organizations… for the purpose of modernizing the radio telescope and putting it into operation".

At present, the Aragats Scientific Centre is financed by a separate special item in the budget (Maintenance and Development of Antenna Standard Complexes, 50 million Drams per year), whose financial means are dissipated within the NIM system: 30 mln. of those means is transferred to the salary fund, 20 mln. are spent on taxes, electricity and other costs, including the purchase of new equipment. The Herouni radio-optical telescope is not financed in these frames.

Nevertheless, the ROT-54/2.6 antenna is in the working state. The movable mechanisms, ensuring the scanning of the antenna beam, engines, manual control system of elevation sensors, a number of automatic control systems, including recording of errors are in the working state. The antenna is provided by a store of feeders. Today, the condition of the collecting surface of the reflector allows stating that without carrying out the alignment and adjustment operations, the antenna has retained the values of its key parameters in the centimetre range.

However, the control system needs modernization; some services need to be restored. It is necessary to carry out alignment and adjustment operations.

II. Basic Data

1. General

Diameter of the main stationary spherical radio reflector	54m	Current state	Without changes
Working diameter (for the given direction of the antenna beam)	32m		Without changes
Diameter of the small radio reflector	5m		Without changes
Overall error of the radio reflector (RMS error)	83 mcm		1mm (rough estimation)
Diameter of optical reflector	2.6m		Without changes
The angle of inclination of the entire system to the south	15°		Without changes
The geographical longitude of the place (East)	40°		Without changes
The geographical latitude of the place (North)	44°		Without changes

2.Radio-technical

Minimal length of the wave		1 mm
Maximal length of the wave		1m
Beam width	on the wave 2 mm	14″
	on the wave 8 mm	1′
	on the wave 20 cm	27′
Temperature of the self-noise	on the wave 3 mm and 8 mm (incl. background noise)	3K
	on the wave 3 cm	9K
	on the wave 20 cm	12K
Geometric surface of the aperture used		800 m^2
Antenna aperture efficiency	on the wave 1 mm (expected)	0.4
	on the wave 2 mm	0.6
	on the wave 8 mm	0.7
Useful surface	on the wave 2 mm	480 m^2
	on the wave 8 mm	550 m^2
Gain factor	on the wave 2 mm	$1.5*10^9$
	on the wave 8 mm	$1.1*10^8$
Aperture angle of the feed		141°
Shading of the used aperture by the small reflector		2.4%

3. Optical

Diffraction-limited resolution	0.2″
Actual resolution	2″
Field angle	40′x 40′
Undistorted field angle	10′x 10′
Collecting surface	5.3m^2
The image sizes of point objects	2″ - 3″

4. Guidance

Apical angle of the conical view		120°
The declinations of the observed sources	from	-35°
	to	+85°
Guidance rate, maximal		40°/min
Acceleration, maximal		1.3°/sec^2
Guidance error	Manual mode (digit. dialling)	3″
	Automatic mode by computer	3″
	Fine manual correction	1″
Support errors	Automatic mode by computer	2″
	Adjusted fine manual correction	1″
Video-guide №1	Field angle	2°x 2°
	Diameter of the lens	30 mm
	Apparent star magnitude	4
Video-guide №2	Field angle	2.5°x 2.5°
	Diameter of the lens	250 mm
	Apparent star magnitude	12

5. Main radio reflector of the antenna

Diameter of the reflector	54m
Shape of the reflector	hemisphere
Curve radius	27m
Inclination of the entire dish to the south	15°
Number of reflector panels	3800

Panel material	Alloy of allum. and zinc
Panel technology	Casting and mechanical treatment
Average weight of the panel	80 kg
Average size of the panel	1m x 1m
Number of the panels sizes	36
Accuracy of the panel surface (RMS error)	10 mcm
Accuracy of the reciprocal array of the panels	±100 mcm
Width of the gaps between panels (aver.)	2 mm
Total error of the main reflector surface (RMS error)	58 mcm
Distance of the panels from the concrete bowl	1.8 m
Length of the panel mounting legs	1.8 m
Diameter of the concrete hemispheric bowl	60 m
Thickness of the concrete bowl	1.5 m
Total weight of the concrete	15,000 t
Total weight of reinforcement	500 t
Total weight of aluminium	360 t
Total volume of excavation	70,000 m^3
Total volume of backfill	57,000 m^3

6. Small radio-reflector of the antenna

Diameter of the reflector	≈5m
Depth of the reflector	≈ 2.5m
Shape of the reflector	special
Distance of the centre of the main reflector from the top of the small reflector	13.5m
Distance of the small reflector top from the focus	3.4m
Surface of the small reflector's aperture	19.6 m^2
Frame	Steel, hard
Number of reflector panels	170
Panel material	titanium
Panel technology	Mechanical treatment
Average sizes of the panels	70 x 40 cm
Accuracy of the panel surface	15 mcm

Reciprocal array of the panels	By the copier
RMS error of the small reflector's surface	60 mcm
Total weight of the small reflector	15 t

7. Optical telescope

Diameter of the main reflector	2.6 m
Shape of the reflector's surface	parabolic
Primary focal length	10 m
Material of the main reflector	Glass ceramics
Ratio of the focal length to the diameter	3.85
Light-gathering power	0.26
Weight of the main reflector	4.2 t
Number of unloading mechanisms	28
Diameter of the secondary reflector	0.4 m
Shape of the secondary reflector's surface	hyperbolical
Total weight of the optical telescope	12 t

8. Support tripod

Length of the supports		≈ 27 m
Size of the cross section of the supports		1.2 x 0.8 m
Weight of each support		12 t
Load on the supports	on the southern	70 t
	on the eastern and western	each 30 t
Diameter of the ring bearer		6 m
Weight of the bearer		20 t
Weight of the turning frame		7.5 t
Total length of the turning structure		30 m
Total weight of the counterweights of the small radio reflector		6 t

Total weight of the turning structure together with the small radio reflector and optical telescope	70 t
Total weight of the support tripod with the turning system	130 t

9. Settings

Panels of the main radio reflector	Number of regulating bolts on each panel	4
	Limits of adjustments (course)	±25 mm
	Pitch (10° turn of the screw)	14 mcm
Panels of the small reflector	Number of regulating bolts on each panel	4
	Limits of adjustments (course)	±15 mm
	Pitch (10° turn of the screw)	14 mcm
Support tripod (3 mechanisms)	Limits of the manual regulation of the leg length	±250 mm
	Pitch of the screw	10 mm
Limits of the automated regulation of the leg length	Pitch (1 turn of the motor)	0.5 mm
	Accuracy of autostabilization of the lengths of the legs	20 mcm
Hanger of the small reflector (3 mechanisms)	Limits of the length regulation	±60 mm
	Step (1 step of the step motor)	10 mcm
	Limits of regulation of the angular position	±6°
	Step (1 step of the step motor)	10″
Mechanisms of radio-focus	Limits of travel in the X and Y axes	±75 mm
	Step (1 step of the step motor)	10 mcm
	Limits of travel in the Z axis	±50 mm
	Step (1 step of the step motor)	10 mcm
	Limits of turning round the axis Z	360°
	Turning step	1°
Mechanisms of optical focus	Limits of travel in the X and Y axes	±35 mm
	Step (1 step of the step motor)	10 mcm
	Limits of travel in the Z axis	±50 mm
	Step (1 step of the step motor)	10 mcm
	Limits of turning round the axis Z	360°
	Turning step	1°

10. Automatic control system

Error of guidance and support		1″- 3″
Total number of electric drives		28
Including:	digital	4
	laser	9
	servo- systems	7
Number of digital sensors angle-code		4
Error of sensors angle-code		2″
Number of control panels		3
Number of observation panels		2
The central control unit carries out in the manual and automatic (computer) modes:		guidance, support, scanning, applications, adjustments, control and indication, communication
Control panel Radio-1 carries out:		scanning, adjustments, control and indication, control of servicing systems
Control panel Optica-1 carries out:		fine correction, adjustments, control and indication, control of servicing systems
Observation panels Radio-2 and Optica-2 carry out:		registration of signals, indication, selection of the signal processing modes in the computer, control

11.Radio receiving equipment

Radiometers of ROT	Wave length, mm/ Frequency, GHz					
	2/138	3/94	8/34	30/10	100/3	200/1.5
Self-noise, K	6400	1900	2300	100	260	200
Sensitivity K (at τ =1 sec, $T_ш$ =300K)	0.3	0.1	0.06	0.02	0.16	0.2

Free transmission range, MHz	1000	1000	3800	800	25	14
Path length to the focus, mm	164	241	221	250	250	250
Stream sensitivity, $(W/m^2 \cdot Hz) \cdot 10^{-27}$ (at S_{eff}=500 m^2)	16.5	5.5	3.3	1.1	8.8	11
Nonlinearity in the dynamic range 25 dB, dB	0.03	0.03	0.03	0.03	0.03	0.03
Input VSWR	1.3	1.2	1.15	1.1	1.1	1.1

These conventional, uncooled radiometers were manufactured in the All-union Scientific Research Institute of Radio measurements under the leadership of P. Herouni.

12. Storage of time

Frequency and time standard Ч1-69	
Nominal value of the output signal frequency	5 MHz, 1 MHz, 100 kHz
Relative error of output signals by frequency within the limits	$\pm 2 \cdot 10^{-11}$
Relative systematic change in frequency in a day within the limits	$\pm 1 \cdot 10^{-12}$

13. Servicing systems

Underground pipe to drain water from the bowl:	
diameter	1m
length	120m
Snow removing system:	
number of heaters with fans (under the main reflector)	60
total power	1 MW
average number of snowing days in a year	20
Number of lifts	3
Folding platform to the radio focus	1
List of other servicing systems:	lighting, washing of the main reflector, communication and messaging, cryogenics, measurements, control of

	covers of the optical telescope, photo guides, and cameras of optical focus, blinds, etc., waterworks, weather station, geodesic points, etc.

14. The ranges of view and the time of observations

The critical aspect angle $\propto_{M}$ is determined by the touch-down of the used and geometric apertures. However, in practice, certain losses of the area (up to 10%) may be acceptable for the sake of increasing that angle. Calculations show that the increase of the critical angle in degrees is numerically equal to the approximate loss of the area in percentage terms.

The possibility of observing these or those celestial sources with the given tool is determined by the view ranges of the antenna, the width of the installation site φ, the source declination, the angle of the possible inclination of the tool towards the south on the whole from Zenith in the plane of the local meridian ψ.

The useful time of observation of the given source depends on the same factors, considering that it is not accepted to work at low dispositions of the source over the horizon as in the thick of the atmosphere with strong gradients, a substantial absorption of the signal and distortions because of the refraction take place. That is why, the sources are usually observed at angles 10-20˚ (and even 30˚) above the horizon.

The mentioned facts refer to both the radio-range and the optical range of the electromagnetic radiation.

In case of ROT-54/2.6, $\varphi = 40°$, $\psi = 15°, 2 \propto_{M} = 120°$, i.e. there is an effective possibility for observing the sources with declinations from δ=-35˚to δ=+85˚. The sources located "lower" than the pole, towards the north horizon in the zone "inaccessible" to observation by ROT, after some time, rotating around the polar axis, will enter the zone of the ROT-54/2.6 observation themselves. Besides, having a gimbal, but not the azimuthal mounting system, ROT does not have a "dead" ("blind") zone around the Zenith point as its axes look at the points on the horizon line, and these points are outside the observation zone.

The observation time for the sources with declinations from δ=-34˚ to δ=+84˚ ranges from 3 to 11 hours a day.

III. The current state of the systems ROT-54/2.6

Electromechanics:

The state of the mechanical systems of the radio-telescope is satisfactory.

The accuracy of the surface of the small reflector has remained unchanged (RMS error = 60 mcm).

The accuracy of the panel surface of the antenna's main radio-reflector and the accuracy of the reciprocal array of the panels have deteriorated, thus alignment and adjustment works are required.

The motors of the gimbal mounting system installed on the antenna operate normally. The small motion motors at the bases of the tripod legs, the radio-focus and optical focus corrections are in the working state.

Control systems:

Most electric drives, digital sensors, and servo-systems are out of order. All the control and observation panels need to be replaced. Many cables, connecting the units of the antenna with the controlling building are lacking.

The computer system needs to be updated. It is necessary to develop new software products.

Radio equipment:

At present, the radiometers are inoperative. In case of further application, it is necessary to reconstruct and repair the entire radio-receiving system.

Electronic digital acquisition system:

Digital acquisition system is lacking. There is a device of analogue acquisition (recorder).

Stabilization systems:

The ruby frequency standard is in an operating state. However, it is necessary to renew the cable system and to develop up-to-date transformation devices. The hydrogen standard is out of order.

Optical telescope:

The cables connecting the control systems of the reflector cover, video-guides, and the video-camera with the control board are lost.

Because of the impossibility of opening the telescope cover mechanically (it is opened only by an automatic command from the control board), it is not possible to estimate the surface of the reflector.

The cooler of the reflector is lacking.

IV. The staff issue

- The scientific school of antenna engineering established by Academician P. Herouni in the Polytechnic University continues to develop under the leadership of A. S. Sargsyan. In the last decade, more than 20 diploma works in the Bachelor and Master programs have been defended, 6 Candidates of technical sciences and more than 10 young engineers have been carrying out their investigations related to the future alignment and adjustment of the antenna of the radio-telescope ROT-54/2.6, its control systems, the antenna measurements, etc.
- In Armenia, there is adequate labour potential with the required engineering qualification. It should be mentioned that the average age of the supposed scientific – technical personnel will not exceed 35.
- Two specialists of optical reflectors are employees of the Aragats scientific centre.
- A. S. Sargsyan is experienced in carrying out radio-astronomic observations.
- There are no radio-astronomers in the scientific staff of the neighbouring Byurakan Astrophysical Observatory, but there are astronomers.

V. The expected steps

Based on the RA Government Resolution, it is proposed to form the Herouni United Space Centre –Hero Centre, under the jurisdiction of the RA Ministry of Economic Development and Investments consisting of the following three units:

- The Aragats Scientific Centre - the radio-telescope ROT-54/2.6 with adjacent structures, the centre area, standard complexes, the corresponding infrastructure and production facilities, the residential quarters;
- The office area in Yerevan – # 49/4, Komitas Av., floors 7-8;
- Testing and experimental plant Wave in Yerevan at the address #25/1, Lepsius Str.

It is supposed that the future General Director of the Herouni United Space Centre will be Candidate of Technical Sciences, Associate Professor Arevik Sargsyan.

In the nearest plans of the start-up staff of the Herouni Centre, a two-stage plan of actions is considered:

1. Targeted brainstorming: Selection of the scientific task, considering the current state of the tool, i.e. the determination of what can be done with minimum expenses and in a minimum period of time. As a result, the frequency range of certain observations will be revealed, application for the acquisition of the required equipment (a receiver with a low-noise amplifier, the devices of the signal acquisition system, etc) will be prepared.
2. Formation of the group of engineers: Engagement of engineers of corresponding specialities (involving curators from abroad), capable of realizing the results obtained at the first stage of activities.