A Prolog

Most of my Scientist and Engineer readers will be members of one of two disciplines, i.e., they will either be from the EM Imaging discipline, or the Coherent Optics discipline. There will of course be other readers, but the following example of Systems level considerations will mainly impact the foresaid disciplines. Furthermore, the bulk of my readers will have their major experience base ***only*** in Systems level work, with only a vague idea of how the science of Systems Architecture has dominated the physical boundaries of their Systems level work in the past (circa 1955 to 2008).

Therefore, it is incumbent upon me to first introduce the overall driving force which prompted the necessity of inventing the ROSÆ – MIRIAH satellite architecture. To begin, it was primarily the necessity of accommodating the overarching dominance of "Demand – Supply" economics in all that we do in this world. And secondarily it was the unifying concept of Shannon's Information Theory, in which the dominance of phase in information systems is recognized. To reinforce this we have seen the growth of coherence in Communications, Navigation, and Imaging. So it is logical to accept a phase dominance in these three applications, and to at least consider the possibility of finding a common denominator in one overarching architecture for all three of these applications, which most completely exploits and emphasizes phase in all of its multi-disciplined systems. Toward this goal, I am confident that the ROSÆ – MIRIAH concept is the quintessential answer. This "answer" is embodied in three Patents, i.e., ROSÆ (patented in 1966), SARAH (patented in 1982), and MIRIAH (Patented applied for in 2001 – now patented).

Then I encourage my readers to first study the chart, which compares the economic rationale for MIRIAH – the primary motivation for this enterprise in the first place (please study this hyper-link before proceeding). Next, I encourage my readers, who are Systems level Engineers and Scientists, to accept that the following Systems level discussion is more heuristic than the kind of rigorous technical work you are accustomed to, since herein I am mainly attempting to acquaint this select group to the kinds of considerations which this new technology offers and requires. For these considerations are vastly different from those you have encountered in the past. In short – this is a training document, not a detailed analysis.

…………………….Bill Grisham

A Benefit/Cost Comparative Evaluation of MIRIAH's Rotating Synthesis Imaging (RSI) and Double Power-Aperture Technology vs.NASA's SIR-C Synthetic Aperture Radar (SAR) and One Power-Aperture Technology.

Warning: *This short technical evaluation was not intended to be either comprehensive or accurate. Rather we intended to emphasize the new trade offs in this new invention, more than we intended to derive accurate answers. For MIRIAH's innovation has opened up new trade offs, which have never before been encountered in the EM discipline. Hence, by offering this brief work, we trust it will open the eyes of Scientists and Engineers in the existing EM technology (SAR, ISAR, INSAR, etc.) to these new trade offs, which must now be accounted for in MIRIAH's new technology. While we did use accurate data from NASA on SIR-C (see the data Annex), and on MIRIAH (from our Math Model), yet the scope of this short treatise did* ***not*** *allow for sufficient depth to render accuracy. We therefore caution the reader to trust in the overall comparative results only if* ***an allowance is made for one or two orders of potential inaccuracy****. That may surprise the reader into thinking this work is of little value, but the magnitude of the Gain, plus the elimination of certain losses due to overly restrictive technical requirements on the existing EM technology, are so huge that even this large inaccuracy is insignificant when compared to the losses this EM discipline has accepted by continuing to use the totally obsolete architectures now in practice.*

The SIR-C is NASA's most efficient SAR. Its satellite antenna area is 12m x 3.5m, or 42 m^2. MIRIAH's antenna area is 0.661 m^2. So, SIR-C's antenna is 63.54 times larger than MIRIAH's. (NOTE: ***the Illumination area is the area served***, and so it is ***directly*** proportional to Economic "Supply". Yet, the Illumination area is ***inversely*** proportional to the antenna area, and ***directly*** proportional to altitude, where SIR-C is at an altitude of about 150 miles. This is why there is a very heavy penalty being paid for the SAR technology in its extremely poor "Supply". This is one of several reasons why the existing EM technology is an economic "loser". Whereas, MIRIAH's much smaller antenna is much higher (about 5,000 miles in altitude) with a much wider beam width, so its "Supply" is not a problem.

MIRIAH's antenna illuminates a ground area of about 1.431 x 10^{13} $meters^2$, or 1.431 x 10^7 km^2 (per "look"). At L Band, MIRIAH has a resolution of 0.06 meters, and a Coherent Gain of 10^{16}, since it is the only known architecture, which uses all of the improvements in RSI (Rotating Synthesis Imaging). At L Band, SIR-C technology has a Swath width of 15 km, covering an area of 225 km^2 (per "look"), and a resolution of 10 meters, and a Coherent Gain of only $10^{3.5}$ to 10^4. So, while MIRIAH's "look by look" area is 63,600 times that of SIR-C's, and its resolution (or pixel area) is about 28,000 times smaller, this is realistic, due to its huge Coherent Gain from the full implementation of Rotational Synthesis Imaging (RSI). ***NOTE: The difference between the SAR technology and the RSI technology is well known to be in totally different classes. But NASA/JPL/SIM's and DoD's Scientists have not been able to enable RSI fully in practice, mainly due to their adherence to a "flat earth" EM Imaging architecture, which adheres to only one Power-Aperture, and adheres to detecting phase on the***

antenna surface, whereas MIRIAH uses ***transceivers*** instead of receivers to bypass the antenna, and then to ultimately detect phase central to its sparse phased array triad at a Matched Filter (MF).

Since served population is proportional to the coverage area, then "$Demand" for MIRIAH can be 63,600 times greater than SIR-C's (***not including*** the ***timeliness*** demand and ***hyper-spectral*** demand, which favors MIRIAH, and so ***the following evaluation is extremely conservative***).

Satellite costs are roughly proportional to satellite weight, and so satellite volume x density. We will compare volumes and densities, using SIR-C data (at the bottom of this document) and MIRIAH's Math Model.

Assuming uniform density and NASA's data, SIR-C's Moments of Inertia ratios ($I_1 : I_2 : I_3$) = (3.5 : 3.5 : 12), when normalized is (1 : 1 : 3.43). MIRIAH's Moments of Inertia will depend on the focal distance of the Matched Filter optics, which will replicate the Illumination Geometry (to scale). MIRIAH's normalized Moments of Inertia will be about (1 : 1 ; 2) to (1: 1: 3), which, as you can see, is comparable to SIR-C's.

SIR-C's volume is about 3.5 x 3.5 x 12 = 147 m^3. MIRIAH's volume (relative to its moments of Inertia of 1:1:2) will be about 0.661 m x 0.661 m x (2 x 0.661 m) = 0.5776 m^3, which would be a small cube structure 15.4 inches on a side (if it were that shape, and had uniform density, whereas the exterior antennae will have very small densities). Again, this difference in SIR-C's huge size vs MIRIAH's tiny size, is due to SAR vs. MIRIAH's "fully implemented" RSI technology.

SIR-C's Coherent Gain is about 10^4, compared to MIRIAH's Coherent Gain of about 10^{16}. Assuming Gain/SNR is proportional to power levels, then MIRIAH's power level adjusted down to SIR-C's Gain/SNR, would be $3000/(10^{16} – 10^4)$ = 0.003 watts, which is again very conservative since MIRIAH's SNR is much higher than SIR-C's. (Again, this is all due to the huge difference in MIRIAH's RSI tech vs SAR tech).

In the Data Annex (below), SIR-C weighs 23.149 # (or 11.6 **Tons**, for both C Band and L Band services). Then the weight for just the L Band portion would be 15, 435 #. Then the density would be about 105 #/ m^3. Also, since both MIRIAH's Math Model results and SIR-C's are for L Band, and power levels drive weight, and antenna size drives volume, then using SIR-C as a reference, MIRIAH's weight will be about (15,435 # x 0.5776 m^3 x 0.003 watts)/(3.5 m x 3.5 m x 12 m x 3000 watts) = 0.000061 # for its power needs (i.e., a ***very*** doubtful number until we have the understanding provided by the Math Model). EM Scientists know that SAR resolution is independent of altitude, and now we have the further improvement of RSI technology, which our Math Model assumes, and the results are indeed surprising in how the ***SNR improves faster than the Range^4 losses*** (in the region from LEO to MEO), leading to unheard of Gain, and so extremely tiny power requirements (never before experienced in EM technology). We have provided an excerpt of one of the three modules, which comprise the Math Model at this hyperlink. So we conclude that we can ignore power requirements as a weight source driver for MIRIAH (whereas for SAR it ***dominates*** the overall design).

Next, since ROSÆ - MIRIAH's 1st and 2nd Moments cancel to zero, then attitude and station keeping systems weights are also very small. So ***MIRIAH's weight will be driven mainly by its structure***, wherein all satellite space structures can be extremely light. Therefore, we estimate a weight, for a MIRIAH*3 satellite's small 0.6 m^3 volume structures, will be only about 200# = 90.72 kg.

Then the Benefit/Cost ratio of MIRIAH will be proportional to this ratio: (coverage area per "look")/(weight) = (1.431 $km^2 \times 10^{13}$/90.72 kg) = 1.58 x 10^{11} km^2/kg. Likewise, the Benefit/Cost ratio of SIR-C would be proportional to this ratio: (coverage area per "look")/(weight) = 225 km^2/10,500 kg = 0.02143 km^2/kg. Then relative to SIR-C, MIRIAH's Benefit/Cost is 1.58 x 10^{11} km^2/kg/0.02143 km^2/kg = 7.373 x 10^{12} times better than SIR-C's Benefit/Cost ratio. This is such a huge number, that we admit our evaluation method is too rough to be acceptable unless we discount one or two orders of magnitude (but you should note the ***huge 10^{13} differences in Coherent Gain proven by the Math Model*** for MIRIAH vs. SIR-C ***almost exactly*** accounts for this number).

Then, there is sufficient evidence herein, for us to claim that there is no legitimate reason for delaying the immediate implementation of the full RSI potential in the MIRIAH enterprise. And NASA, and DoD, will simply have to "bite the bullet" by expediting MIRIAH to augment SAR technology's limitations in favor of the uncompromised RSI technology inherent in MIRIAH's architecture and its ***full*** implementation of ***maximum*** RSI Gain (or maximum energy compression) via Matched Filter recording onto a nanotechnology disc(s)). For, MIRIAH enables far greater energy density compression than is possible within the existing limitations of the older EM technology's obsolete architecture (**a truth which rests solidly upon the Law of Conservation of Energy**).

By Bill Grisham, ROSÆ, Inc.

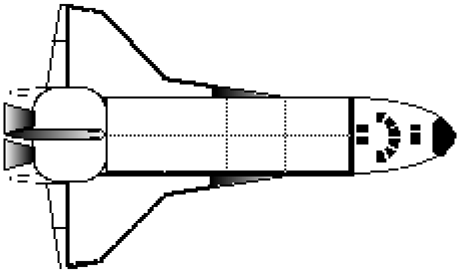
SIR-C Data Annex

What is SIR-C/X-SAR?

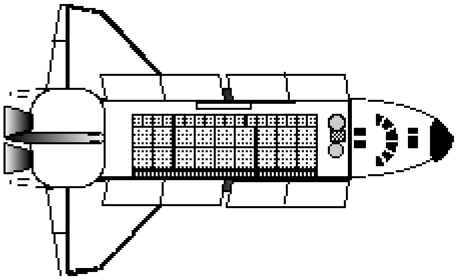
SIR-C/X-SAR stands for Spaceborne Imaging Radar-C/X-band Synthetic Aperture Radar. SIR-C/X-SAR is an imaging radar system scheduled for launch aboard the NASA Space Shuttle in 1994. It consists of a radar antenna structure and associated radar system hardware that is designed to fit inside the Space Shuttle's cargo bay. On take-off, the cargo bay doors are closed as seen in the graphic on the next page. After the Space Shuttle has reached a stable Earth orbit, the cargo bay doors will be opened , the antenna structure will be deployed, and SIR-C/X-SAR will be switched on, to begin using its state-of-the-art radar technology to image the earth's surface. Radar images generated by

SIR-C/X-SAR will be used by scientists to help understand some of the processes which affect the earth's environment, such as deforestation in the Amazon, desertification south of the Sahara, and soil moisture retention in the Mid-West.

Deploying SIR-C



Space Shuttle doors closed



Space Shuttle doors open, showing SIR-C/X-SAR antenna

The SIR-C/X-SAR Project

SIR-C/X-SAR is a joint project of the National Aeronautics and Space Administration (NASA), the German Space Agency (DARA) and the Italian Space Agency (ASI). It is the next step in a series of spaceborne imaging radars, beginning with SEASAT in 1978, continuing with SIR-A (1981), Germany's Microwave Remote Sensing Experiment (1983), and SIR-B (1984). It is a precursor to the Earth Observing System (EOS) imaging radar system planned for the end of the decade.

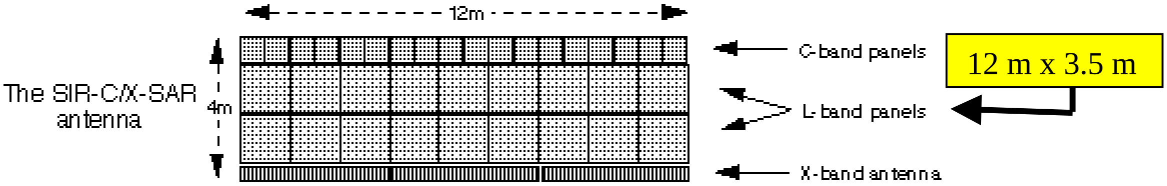
Science Objectives

SIR-C/X-SAR's unique contributions to Earth observation and monitoring are its capability to measure, from space, the radar signature of the surface at three different wavelengths, and to make measurements for different polarizations at two of those wavelengths. SIR-C image data will help scientists understand the physics behind some of the phenomena seen in radar images at just one wavelength/polarization, such as those produced by SEASAT. Investigators on the SIR-C/X-SAR Science team will use the radar image data from SIR-C/X-SAR to make measurements of the following:

- Vegetation type, extent and deforestation
- Soil moisture content
- Ocean dynamics, wave and surface wind speeds and directions
- Volcanism and tectonic activity
- Soil erosion and desertification

SIR-C/X-SAR Instrument Description

The SIR-C/X-SAR antenna structure actually consists of three individual antennas, one operating at L-band (23.5cm wavelength), one at C-band (5.8cm wavelength) and the third at X-band (3cm wavelength). The L-band and C-band antennas are constructed from separate panels that can measure both horizontal and vertical polarizations.



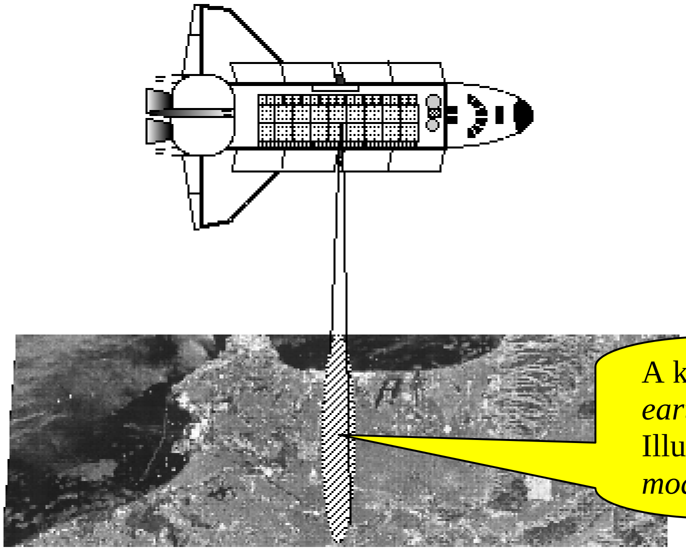
12 m x 3.5 m

The SIR-C/X-SAR antenna is the most massive piece of hardware (at a total of 10,500 kilograms) ever assembled at the Jet Propulsion Laboratory, and measures 12 meters by 4 meters. The SIR-C instrument was built by JPL and the Ball Communication Systems Division for NASA and provides the L-band and C-band measurements at different polarizations. The L-band and C-band antennas employ phased array technology, which allows the antenna beam pointing to be adjusted electronically. The X-SAR instrument is built by the Dornier and Alenia Spazio companies for DARA and ASI and operates at a single frequency, X-band. The X-SAR antenna is a slotted waveguide type, which uses a mechanical tilt to change the beam pointing direction.

23,149 # = 11.6 Tons

SIR-C/X-SAR Image Data

During a week-long Shuttle flight, SIR-C/X-SAR will image an area of roughly 50 million square kilometers of the Earth's surface. This corresponds to a total of 50 hours of data. The peak data rate will be 225 megabits (or 225,000,000 bits) per second. The data collected will be processed into images with resolution selectable from 10 to 200 meters. The width of the area mapped out by the radar will vary from 15 to 90 kilometers, depending on how the radar is operated, and the direction in which the antenna beams are pointing. Data from SIR-C/X-SAR will be used to develop automatic techniques for extracting information from radar image data, in preparation for the EOS SAR mission later in the decade.



A kind of “*wiper blade*” illumination, and a “***flat** earth*” modeled architecture, whereas MIRIAH’s Illumination is ***circular*** and its *architectural model for the raw data is a **sphere**.*

This schematic diagram shows the SIR-C/X-SAR antennas illuminating an area on the ground, and mapping out a swath as the Shuttle moves forward. The area shown is a SEASAT image of Los Angeles, California. North is to the right of the image shown.

More About SIR-C/X-SAR

The Shuttle Imaging Radar-C and X-Band Synthetic Aperture Radar (SIR-C/X-SAR) is a cooperative space shuttle experiment between the National Aeronautics and Space Administration (NASA), the German Space Agency (DARA), and the Italian Space Agency (ASI). The experiment is the next step forward in NASA's Spaceborne Imaging Radar (SIR) program that began with the Seasat Synthetic Aperture Radar (SAR) in 1978, and continued with SIR-A in 1981 and SIR-B in 1984. The program will eventually lead to TOPSAT, a mission to measure topography globally, and the Earth Observing System (EOS) SAR later in this decade. The program also benefits from experience gained with the Magellan Mission to Venus, other international spaceborne radar programs (e.g. ERS-1, JERS-1), and prototype aircraft sensors such as the JPL Airborne SAR (AIRSAR).

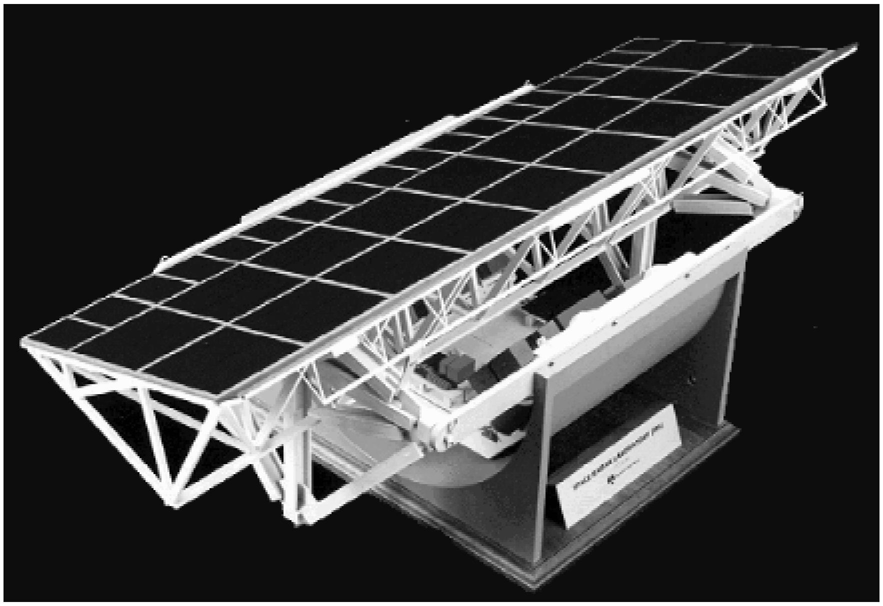
SIR-C will provide increased capability over SEASAT, SIR-A, and SIR-B by acquiring digital images simultaneously at two microwave wavelengths ([[lambda]]): L- band ([[lambda]] = 23.5 cm) and C-band ([[lambda]] = 5.8 cm). These vertically- and horizontally-polarized transmitted waves will be received on two separate channels, so that SIR-C will provide images of the magnitude of radar backscatter for four polarization combinations: HH (Horizontally-transmitted, Horizontally-received), VV (Vertically-transmitted, Vertically-received), HV, and VH; and also data on the relative phase difference between the HH, VV, VH, and HV returns. This allows derivation of the complete scattering matrix of a scene on a pixel by pixel basis. From this scattering matrix, every polarization configuration (linear, circular or elliptical) can be generated during ground processing. The radar polarimetric data will yield more detailed information about the surface geometric structure, vegetation cover, and subsurface discontinuities than image brightness alone.

Germany's imaging radar program started with the Microwave Remote Sensing Experiment (MRSE) flown aboard the Shuttle. This X-band radar was flown on the first SPACELAB mission in 1983. The program was continued by development of the X-SAR, for which cooperation with Italy was initiated. X-SAR, will operate at X-band ([[lambda]] = 3.1 cm) with VV polarization, resulting in a three-frequency capability for the total SIR-C/X-SAR system. Because radar backscatter is most strongly influenced by objects comparable in size to the radar wavelength, this multi-frequency capability will provide information about the Earth's surface over a wide range of scales not discernible with previous single-wavelength experiments.

SIR-C/X-SAR Instrumentation

SIR-C will provide multi-frequency, multi-polarization radar data. The SIR-C instrument is composed of several subsystems: the antenna array, the transmitter, the receivers, the data-handling subsystem, and the ground SAR processor. The antenna is composed of two planar arrays, one for L-band and one for C-band. Each array is composed of a uniform grid of dual-polarized microstrip antenna radiators, with each polarization port fed by a separate corporate feed network. The overall size of the SIR-C antenna is 12.0 x 3.7 meters and consists of three leaves each divided into four subpanels.

Model of the SIR-C/X-SAR antenna



Unlike previous SIR missions, the SIR-C radar beam is formed from hundreds of small low power solid state transmitters embedded in the surface of the radar antenna. By properly phasing the energy from these transmitters, the beam can be electronically steered in the range direction +/-23deg. from the nominal 40deg. off nadir position without physically moving the large radar antenna. This feature will enable images to be acquired over a wide range of incidence angles.

X-SAR will provide VV polarization images using a passive slotted waveguide antenna measuring 12.0 x 0.4 meters. Other X-SAR components include a traveling wave tube as transmitter, an exciter, receiver, and data handling subsystem. A mechanical tilt mechanism will point the X-SAR antenna to angles between 15 and 60deg., in the same direction as the L-band and C-band beams.

Both SIR-C and X-SAR can be operated as either stand alone radars or together. Roll and yaw maneuvers of the shuttle will allow data to be acquired on either side of the shuttle nadir (ground) track. The width of the imaged swath on the ground varies from 15 to 90 kilometers (9 to 56 miles) depending on the orientation of the antenna beams and the operational mode. Table 1 presents a summary of the SIR-C/X-SAR system characteristics.

Table 1: SIR-C/X-SAR System Characteristics

PARAMETER	L-BAND	C-BAND	X-BAND
Wavelength	0.235 m	0.058 m	0.031 m
Swath Width	15 to 90 km	15 to 90 km	15 to 40 km
Pulse Length	33.8, 16.9, 8.5 us	33.8, 16.9, 8.5 us	40 us
Data Rate	90 Mbits/s	90 Mbits/s	45 Mbits/s
Data Format	8,4 bits/word	8,4 bits/word	8,4 bits/word
	(8,4) BFPQ	(8,4) BFPQ	(8,4) BFPQ

BFPQ = Block Floating Point Quantization, a form of data compression from 8 bits per sample to 4 bits per sample.

SYSTEM PARAMETERS:

Orbital Altitude	225 km
Resolution	typically 30 x 30 m on the surface
Look Angle Range	17 to 63 degrees from nadir
Bandwidth	10, 20 and 40 MHz
Pulse Repetition Rate	1395 to 1736 pulses per second
Total Science Data	50 hours/channel/mission
Total Instrument Mass	11,000 kg
DC Power Consumption	3000 to 9000 W