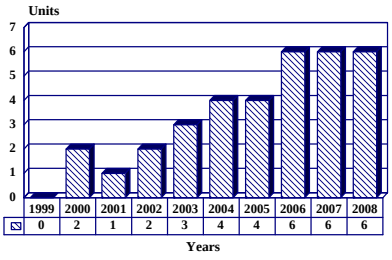
Kollmorgen Non-Penetrating Periscopes - Archived 10/2000

Outlook

- Revolutionary new technology, eliminating through-hull hole
- Once up to speed, likely to be a key player in an emerging niche
- Presently competing for Britain's Astute class contract
- Majority of sales expected for US platforms
- Retrofits possible, to boost performance of SSNs, SSBNs

10 Year Unit Production Forecast
1999 - 2008



Orientation

Description. Non-penetrating two-stage periscopes for submarines, consisting of a sensor unit, a modular mast unit, and a display and control unit.

Sponsor

US Navy
Naval Sea Systems Command (NAVSEA)
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USA
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Contractors

Kollmorgen Corp
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USA
Tel.: +1 413 586 2330
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(optical components, electronics)

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Calzoni Division
Via Emilia Ponente 72
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(telescope and hoist systems)

Licensees. No production licenses have been granted.

Status. Second generation unit in service with US SSN. Production contract awarded for three systems in 1995.

Total Produced. Two generations prototyped. Production contract awarded in 1995. Two or three production models have probably been built by now.

Application. Above-water imaging of submarines.

Platform. The Model 86 non-penetrating periscope will be used on the US Navy's Seawolf and New Attack Submarines (NSSN), operating in all-optronic configuration. Export sales opportunities for the system include all potential new construction submarine programs.

Price Range. Based on a 1995 contract price, a unit cost of US$6.9 million was assumed, including design, development, fabrication and testing. It is not known how much of the associated development costs are built into the price of the product itself, however.

The competing Zeiss/Pilkington system was quoted as costing around US$2.9 million in late 1998, including the mast with a standalone operator console. Kollmorgen has traditionally been very competitive on price, but the current unit cost is not disclosed.

Technical Data

Characteristics	**Thermal Imaging Function**
Fields of view	NFOV: 4.4°, WFOV: 10°H x 7.5°V
Closed Cycle Cooler	MTBF > 2500 hours
Elevation Range	-10° to +55°
Television Function	
Color Resolution	>500 lines
Fields of View	NFOV: 4.4°H x 3.3°V; MFOV: 10°H x 7.5°V
Shutter	Electronic
Specifications	
Pressure Resistance	68 bar (hydrostatic)
Operating Speed	12 knots
Data Interference with Submarine	RS422 (other formats available)
Power Requirements	115 V-60 Hz (2000 W)

Design Features. The Model 86 is a non-penetrating two-stage modular electro-optical sensor system, developed by Kollmorgen to replace conventional periscopes. The US Navy version uses a modular hoist mast, developed in cooperation with Italy's Riva Calzoni. The system's main components are the Sensor Unit, Rotation Unit, Mast Unit, Interface Electronics Rack Units, and the Display and Control Console.

The Universal Modular Mast System being developed for the US Navy has been derived from the one-stage unit, previously built by Riva Calzoni.

The Model 86 system offers thermal imaging for day and night viewing, and color television for daylight viewing. It has a built-in two-axis stabilization feature, intended to eliminate effects of the ship's motion and mast vibration. A unique, statically sealed rotating sensor package is also incorporated in the system.

The optronic head itself (Sensor Unit) contains two windows arranged vertically. The oval-shaped top window contains two visual cameras: a black-and-white HDTV camera, and a high-resolution color CCD. Three alternately selectable fields of view are available (22.8°, 10° or 4.4°).

The lower, circular window serves an eight-element SPRITE FLIR, which has fields of view of 10 degrees and 4.4 degrees. The FLIR operates in the 8-12 micron range, with 3-5 microns available as an option. The main television window and CCD camera form the primary optical path, with a rotating mirror behind the FLIR window directing the image down the periscope to a thermal camera. The mast control can be carried out in manual or automatic mode with a quick look feature. All sensors are stabilized in two axes.

Video connections are completed by both a coaxial cable and a rotary fiber-optics joint; there is no waveguide connector to the ESM array. The ESM system can be customer-specified. At present, the ESM array uses copper cable; later, this will be probably replaced by a system in which the ESM equipment digitizes the data at the masthead and sends it down in optical form. The ESM housing can also optionally accommodate a global positioning system (GPS) facility.

Operational Characteristics. The Model 86 periscope head allows the submarine a quick look at the operating environment without a lengthy stay on the surface. It is capable of a sector scan in less than two seconds, and a full circular scan in 5-6 seconds, when using a black-and-white camera. Automatic modes are provided for programmed horizon and hemisphere search, also contributing to the short above-surface time needed to establish a view of the area.

The optical path includes an electronic zoom feature, in a fully reconfigurable Windows environment. The electronic transmittal of the data means the image can be enhanced in real time; information can be recorded for later retrieval, further analysis and interpretation. Electronic processing and storage of the information makes the use of the data more flexible in terms of time and place, and the information can be enhanced for improved observation of details, if necessary.

Kollmorgen's Model 86 non-penetrating optronic peri-scope has already gone from its second generation

to the third, between 1995 and 1997. The features described above apply primarily to the first generation versions, which have had color, black and white, and LWIR (8-12µm) cameras; HMI; ESM; and a Rotational Unit and a Modular Mast. With no reported failures to date (Summer, 1998), the Rotational Unit features pressure compensation, slip ring, data transmission and a rotary drive motor. The Modular Mast, including pressure proof cable belt, also has no recorded failures to date.

The second generation system has improved color, B&W, and MWIR (3-5µm) cameras and X-Windows (Motif HMI). It also features a state of the art workstation, with image processor and system processor, and support electronics. A third generation version is under contract for delivery in early 1997, but technical specifications have not yet been released. By mid-1997, it was not known whether a delivery had yet been made.

Variants/Upgrades

The **options** to the basic Model 86 mast hardware and/or software and functions include the following:

ESM. The Model 80 Optronic Mast has been designed to accept several different variations of ESM systems. Exact configurations will depend on customer requirements. A system capable of integration with the Model 86 typically has a frequency coverage of 2-18 GHz, and a -65 dBmi sensitivity. Omni directional warning or alternatively Direction Finding can be implemented in the ESM as desired.

Communications/Navigation. The Model 86 Optronic Mast Series is capable of being fitted with several variations of radio frequency transmit and/or receive antennas, including VPA. The antennas can also be selected to provide a GPS navigation capability.

Standard Console Interface. The system can be interfaced to the submarine's existing or planned multifunction consoles. Optional Optronic Mast control software and display software can be supplied, for porting to multifunction consoles.

Additional optionals include the following:

- **Monochrome or Intensified Monochrome Television Camera**
- **8-12 Micron Thermal Camera**
- **Laser Rangefinder/Video Rangefinder**
- **Automatic Video Tracking**
- **Image Recording**
- **Image Processing**

Further *alternative configurations of periscope shipsets* can be provided by the manufacturer, to meet any specific operational requirements. For instance, one of the series of Model 86 Optronic Masts can be integrated with a Model 76 Attack Periscope. Model 76 is a mature, reliable design, which is in production and in use at sea by eight navies.

Another alternative would be to incorporate the system with the Model 90 Penetrating Optronic Periscope, characterized as one of the world's most advanced periscopes. In both cases, the system can utilize a Kollmorgen Imaging Center or a Combat System Standard Console.

Program Review

Background. While submarines' above-water imaging requirements were traditionally met by optical periscopes, from the early part of the 20th century until the 1970s, significant changes have taken place over the last two decades, with combinations of periscopes and electronic sensors satisfying selected visual requirements. These optronic periscopes (thus called for combining optics and electronics) offer additional benefits, such as Image Intensifiers, Low Light Level TVs or IR cameras and a number of ESM and communications antennas.

Furthermore, during the mid-1980s, Kollmorgen anticipated that the submarines being designed at the time would remain operational well into the 21st century. They would have to function in the face of an extremely unpredictable threat profile, and undertake operations quite different from those originally envisaged. This new operational environment would require periscope capabilities far in excess of the then-current generation.

Submarines were foreseen functioning increasingly in littoral areas, in green and brown waters, and because of the more shallow water, in more crowded environments, In such circumstances surfacing would have very critical significance for the operation, even more so than traditionally.

On the other hand, other types of submarines could be fitted to enter even greater depths of blue water areas, i.e., needing more structural strength than before. This would be best achieved by eliminating the penetrating periscope, in lieu of one that required a major structural weak point in a unit otherwise optimized for great diving depths.

The company also came to the conclusion that the demands placed on a new generation of periscopes, in terms of sensor integration, data accumulation and reduced exposure time, could best be met by the adopting a non-penetrating mast solution. This led to the development of the Model 86 periscope, the first to combine viewing and electromagnetic sensors on a single non-penetrating mast.

Meanwhile, parallel to Kollmorgen's own efforts, the US Navy had decided to adopt a non-penetrating mast solution for the periscopes on the new Seawolf class attack submarines. In 1987 and '88, Kollmorgen was awarded contracts for experimental work in this area and for the development of a prototype mast.

In late February 1989, Kollmorgen teamed with Riva Calzoni of Italy, to develop a new generation of non-penetrating mast and sensor systems for submarines of the US, Italian, and other NATO, as well as selected other navies. This agreement combined Kollmorgen's expertise in electro-optics, with Riva Calzoni's in designing elevating mast assemblies.

The prototype mast produced by Kollmorgen under the 1988 contract was installed on the US Navy test submarine *Memphis*. The equipment underwent a five-year trials program and was removed in 1993. This equipment was refurbished with new sensors, electronics and ESM, and returned to service in 1994. The system is still in operation aboard a US SSN.

The Request For Proposals (RFP) for an operational non-penetrating mast assembly was issued in January 1992, and by July 1992, bids for a non-penetrating mast had been received from the following consortiums: Kollmorgen/Riva Calzoni/Librascope/Unisys; General Electric/Zeiss; Raytheon/GEC/SAGEM; Rockwell/Barr and Stroud/McTaggart Scott/Watkins Johnson; and Sperry Marine/Martin Marietta/Texas Instruments.

Not unexpectedly, this contract was won by Kollmorgen, who received a US$7 million order to develop production systems in May 1995.

The advantages accrued by the adoption of non-penetrating periscopes are fundamental. In tactical terms, the electronic image can be fused with other data, such as sonar signatures or ESM system output. This provides the submarine commander with a much more extensive and comprehensive view of the tactical situation, added to the fact that the submarine needs to stay on the surface only a few seconds to gather image data.

A very key point is that the data can be subsequently displayed on a large-screen console and scrubbed electronically to enhance and sharpen the image. In short, the commander can see more, see better and understand what he is seeing faster. This further enhances the submarine's effectiveness and survivability.

The use of non-penetrating technology also has significant design and structural benefits to the boat itself. The most obvious is the elimination of the opening in the pressure hull required by the periscope shaft. Most discussions of submarine diving depth focus on the strength of the pressure hull itself, while the fact that the integrity of the penetration seals are also a critical factor, is often ignored. Seal integrity is directly correlated to the diameter of the hole in question: the periscope shaft is one of the worst offenders. Thus, adopting a non-penetrating mast has direct and immediate benefits on the hull's strength and, thus, underwater performance.

A more subtle design advantage is that the adoption of electro-optical technology means that the control room can be positioned freely within the hull and laid out in the most efficient manner possible.

Considerable opposition remains to the non-penetrating periscope technology from within the submarine community itself, and stems, in part, from that community's inherent conservatism. Indeed, there are good and sound justifications for that position. An optical periscope will always work, regardless of power or computer failures. In an emergency, it can be winched up manually. Any electrical failure or computer crash takes a non-penetrating electro-optical periscope out, until the system as a whole can be brought up again.

Furthermore, the quality of the electronic image is only coming of age, producing optical resolution comparable to the traditional periscope, albeit at an increasingly more affordable price. Formerly, the reliability and performance of LLLTV and IR sensors were poor.

For these reasons, it is doubtful that complete reliance will be placed on non-penetrating solutions, until the technology has been demonstrated to work under all circumstances and at all times. In the short term, it is projected that a conventional periscope will be retained as a back-up in most designs. Transition to full optronics operation will take some time and a change in mind set, not unlike the introduction of the digital displays of the sonar data.

Having said that, however, reliability and performance of modern sensors are sufficiently improved, so that the US New Attack Submarine (NSSN) will rely exclusively on optronic, as will Sweden's projected Viking submarine (Submarine 2000). While the new British Astute class will also be fully optronic in its periscope configuration, it is highly unlikely that the American Kollmorgen would be chosen over the domestic Pilkington's Barr & Stroud.

Kollmorgen is making both the Model 86 and the penetrating type Model 90 technologies available for export, thus offering different options for modular construction. The link with Riva Calzoni makes Italy a primary prospect for an early export sale, particularly since it is behind in the mast construction. This would probably be the case with the Type 212 submarines, being built in Italy off German license. On the other hand, it may be possible that Germany's Zeiss has been able to strong-arm its product on these submarines as well.

In 1999, Kollmorgen announced that it has fully taken over its Italian partner, Riva Calzoni. This move was not totally unexpected, since the two had been collaborating closely for some time, presumably under an arrangement with financial support/an ownership stake by Kollmorgen in Riva. (It was difficult to see Riva as succeeding independently in the field where the number of players was very limited, product development costs high, and manufacturing required highly specialized equipment and labor force that was, in the end, only scarcely available.) The market these days consists of only so many new-build programs, with most of the submarine builders tied to a compatriot electronics/optics supplier. The chances for exports are very limited indeed. For the US side of this team, the amalgamation of forces makes financial sense, since Italy's relatively advantageous labor rates will help keep Kollmorgen/Riva product prices competitive in the tight European/international market.

Funding

Development of the Model 86 periscope program was funded by Kollmorgen Corporation. The US government program to develop a non-penetrating mast was undertaken by the Advanced Research Projects Agency (ARPA) and funded under Program Element No. 0603226E.

Recent Contracts

Contractor	Award ($ millions)	Date/Description
Kollmorgen	7	*July 1994* – Upgrading the NPP with second generation sensors, electronics, software.
Kollmorgen	35	*January 1995* – Production of the Photonics Mast. Work to be carried out in partnership with Hughes Aircraft Company Electro Optical Systems, Raytheon, and AEL Industries.
Kollmorgen, Riva Calzoni	6.9	*May/June 1995* – Design, development, fabrication testing and delivery of the Universal Modular Mast (UMM) system [hoist for the two Photonics Masts, as well as all other above-water sensors/antennas] for the New SSN.
Kollmorgen	10.2	*May 1998* – Delete one Engineering and Development Model (EDM) and reconfigure one EDM into a pre-production unit under the Photonics Mast Program.

Timetable

Month	Year	Major Development
	1976	Kollmorgen develops initial optronic concepts for US Navy review
	1980s	Kollmorgen begins developing non-penetrating systems
	1988	USN system development started
Feb	1989	Joint venture with Riva Calzoni announced
	1991-1993	Trial operation of optronic mast on USS *Memphis*

Month	Year	Major Development
	1992-1993	First Generation Model 86 Optronic Mast operational validation
	1994	Contract issued for Second Generation Optronic Mast
Early	1995	Development and initial production contract
	1995-present	Second Generation Model 86 at sea
	1997	Third Generation Photonics Mast deliveries begin
	1998	Bidding for delivery on Britain's Astute class submarines
	1999	Kollmorgen takes over Riva Calzoni

Worldwide Distribution

US (System under development for New SSN submarines. Second generation system in service. Retrofits expected for modernizing the Los Angeles and Ohio classes, possibly also for the Seawolf).

Forecast Rationale

The US Navy Virginia class attack submarine (formerly known as NSSN) is presently the only major building program that Kollmorgen has practically ensured for this new technology thus far. The bidding for Britain's upcoming Astute class systems continues, but as stated last year, the likelihood of that submarine carrying an American – or "American-Italian – optronic mast system is very tiny indeed. Britain's own Pilkington, which in the meantime has joined forces with Germany's Zeiss, one of the lead players in this segment as well, would be the natural choice for that project. Nevertheless, no decision on the Astute optronics system has been announced as yet, and "all is quiet on the western front".

The Virginia class is already under construction, with contracts for the first four already under way. The class might eventually include as many as 30 boats, spread over a building and launching period of 2-3 boats a year. Even if all of those are not built, some other class will be introduced as its successor. The US Navy must maintain its submarine forces at a level that will provide certain undersea defense capabilities, despite the intended reductions in the overall fleet strength.

In addition to the new-sales for the Virginia class, there may also be retrofit activity on the Ohio and Los Angeles submarines of the USN. That, however, is an increasingly shrinking possibility, since the number of SSBNs is being reduced to 12, the new Virginia class is developing, and conversion work is rather expensive. On the other hand, those boats do have substantial amounts of service life left in them, and improving their performance would be a sensible solution for utilizing these assets even more effectively.

The Seawolf class is not likely to see retrofits of these optronic masts until around their midlife refueling, when the boats are already pulled up to the docks for that work

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

			High Confidence Level				Good Confidence Level				Speculative			
Designation	Application	Thru 98	99	00	01	02	03	04	05	06	07	08	Total 99-08
MODEL 86	SSN/SSBN (USN)	2	0	1	1	2	2	3	3	4	4	4	24
MODEL 86	SSN/SSBN (VARIOUS)	0	0	1	0	0	1	1	1	2	2	2	10
Total Production		2	0	2	1	2	3	4	4	6	6	6	34