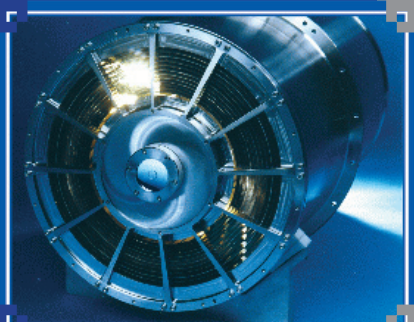
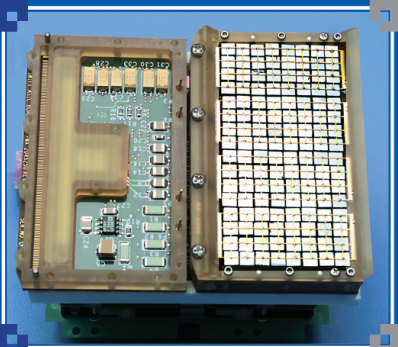


# Swift Explorer

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## News Media Kit



November 1, 2004

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Nov. 1, 2004

Nancy Neal  
Goddard Space Flight Center, Greenbelt, Md.  
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## **RELEASE: 04-360**

### **NEW NASA SATELLITE TO STUDY BLACK HOLE BIRTH AND GAMMA RAY BURSTS**

By the end of this day, somewhere in the visible universe a new black hole will have formed. Gamma-ray bursts (GRBs), the most distant and powerful explosions known, are likely the birth cries of these new black holes.

NASA's Swift mission is dedicated to studying the gamma-ray burst/black hole connection. The Swift spacecraft, an international collaboration, is scheduled to lift off on November 17, 2004 aboard a Delta II rocket from Cape Canaveral Air Force Station, Fla.

"Swift caps off a 30-year hunt to understand the nature of gamma-ray bursts, flashes of light that burn as brightly as a billion billion suns," said Dr. Anne Kinney, Director of the Universe Division, NASA Headquarters, Washington. "Swift is fine-tuned to quickly locate these bursts and study them in several different wavelengths before they disappear forever. Swift is a little satellite with a big appetite," she said.

Gamma-ray bursts are fleeting events, lasting only a few milliseconds to a few minutes, never to appear in the same spot again. They occur from our vantage point about once a day. Some bursts appear to be from massive star explosions that form black holes.

The Swift observatory comprises three telescopes, which work in tandem to provide rapid identification and multi-wavelength follow-up of GRBs and their afterglows. Within 20 to 75 seconds of a detected GRB, the observatory will rotate autonomously, so the onboard X-ray and optical telescopes can view the burst. The afterglows will be monitored over their durations, and the data will be rapidly released to the public.

The afterglow phenomenon follows the initial gamma-ray flash in most bursts. It can linger in X-ray light, optical light and radio waves for hours to weeks, providing great detail. The crucial link here, however, is having a precise location to direct other telescopes. Swift is the first satellite to provide this capability with both great precision and speed. "We expect to detect and analyze over 100 gamma-ray bursts a year," said Dr. Neil Gehrels, Swift's Principal Investigator at NASA's Goddard Space Flight Center (GSFC) in Greenbelt, Md. "Swift will lead to a windfall of discovery on these most powerful explosions in the universe."

While the link between some bursts and massive star explosions appears firm, other bursts may signal the merger of neutron stars or black holes orbiting each other in exotic binary star systems. Swift will determine whether there are different classes of gamma-ray bursts associated with a particular origin scenario. Swift will be fast enough to identify afterglows from short bursts, if they exist. Afterglows have only been seen for bursts lasting longer than two seconds.

“Some bursts likely originate from the farthest reaches, and hence earliest epoch, of the universe,” said Swift Mission Director John Nousek. He is a professor of astronomy and astrophysics at Penn State’s University Park, Pa., campus. “They act like beacons shining through everything along their paths, including the gas between and within galaxies along the line of sight,” he said.

Swift notifies the community, which includes museums, general public, and scientists at world-class observatories, via the GSFC-maintained Gamma-ray Burst Coordinates Network (GCN). A network of dedicated ground-based robotic telescopes distributed around the world awaits Swift-GCN alerts. The Swift Mission Operations Center, located at Penn State’s University Park campus, controls the Swift observatory and provides continuous burst information.

Swift, a medium-class explorer mission, is managed by GSFC. Swift is a NASA mission with participation of the Italian Space Agency and the Particle Physics and Astronomy Research Council in the United Kingdom. It was built in collaboration with national laboratories, universities and international partners, including Penn State University; Los Alamos National Laboratory in New Mexico; Sonoma State University, Rohnert Park, Calif.; Mullard Space Science Laboratory in Dorking, Surrey, England; the University of Leicester, England and the Brera Observatory in Milan, Italy.

More information about Swift is available at: <http://swift.gsfc.nasa.gov>

## Media Services Information

### NASA Television Transmission

NASA TV is available on the Web and via satellite in the continental U.S. on AMC-6, Transponder 9C, C-Band, at 72 degrees west longitude. The frequency is 3880.0 MHz. Polarization is vertical, and audio is monaural at 6.80 MHz. In Alaska and Hawaii, NASA TV is available on AMC-7, Transponder 18C, C-Band, at 137 degrees west longitude. The frequency is 4060.0 MHz. Polarization is vertical, and audio is monaural at 6.80 MHz.

For NASA TV information and schedules on the Internet, visit:

*<http://www.nasa.gov/ntv>*

### Audio

Audio only will be available on the V circuits that may be reached by dialing 321-867-1220, -1240, -1260, -7135, -4003, or -4920.

### Prelaunch Press Conference

The prelaunch press conference will be held at the NASA News Center at Kennedy Space Center on Tuesday, Nov. 16, at 1 p.m. EST. Participating in the briefing will be:

- Dr. Anne Kinney, Director, the Universe Division, Science Mission Directorate NASA Headquarters, Washington, D.C.
- Chuck Dovale, NASA Launch Manager/Launch Director, KSC, Florida.
- Kris Walsh, Director of NASA Programs, Boeing Expendable Launch Systems, Huntington Beach, California.
- Mark Edison, Spectrum Astro Swift Program Manager, Spectrum Astro, Gilbert, Arizona.
- Joe Dezio, Swift Project Manager, Goddard Space Flight Center, Greenbelt, Maryland.
- Joel Tumbiolo, USAF Delta II Launch Weather Officer, 45th Weather Squadron, Cape Canaveral Air Force Station, Florida.

### Swift Mission Science Briefing

A mission science briefing will immediately follow the prelaunch press conference. Participating will be:

- Dr. Paul Hertz, Assistant Associate Administrator for Science, Science Mission Directorate, NASA Headquarters.
- Dr. Neil Gehrels, Principal Investigator, Goddard Space Flight Center, Greenbelt, Maryland.
- Dr. Alan Wells, United Kingdom X-ray Telescope Lead, University of Leicester, UK.
- Dr. Guido Chincarini, Swift Italian Science Team Lead, Brera Observatory and University of Milan at Bicocca, Italy.

All briefings will be carried live on NASA Television and the V circuits.

## **News Center/Status Reports**

The Swift News Center at KSC will open on November 15 and may be reached at 321-867-2468. Recorded status reports will be available beginning November 15 at 321-867-2525 and 301-286-NEWS.

## **Launch Media Credentials**

National media desiring launch accreditation information should contact the KSC Newsroom by close of business on November 14. Foreign national must have their accreditation paperwork in 30 days before launch. All paperwork should be sent to:

Kandy Warren, Office of Public Affairs  
KSC Media Accreditation Officer  
Swift Launch Accreditation  
NASA XA-E1  
NASA Kennedy Space Center  
Kennedy Space Center, Fla. 32899  
Telephone: 321-867-7711 or -7819  
Fax: 321-867-2692

Requests must be on the letterhead of the news organization and must specify the editor making the assignment to cover the launch.

### **Internet Information**

More information on the NASA's Swift mission, including an electronic copy of this press kit, press releases, fact sheets, status reports and images, can be found at:

*[http://www.nasa.gov/mission\\_pages/swift/main/index.html](http://www.nasa.gov/mission_pages/swift/main/index.html)*

*<http://www.gsfc.nasa.gov>*

Swift mission information can be found at:

*<http://swift.gsfc.nasa.gov>*

## Swift Quick Facts

- Mass: 1470 kg
- Power: 1040 Watts
- Cost: \$250 million including contributions from the UK and Italy
- Collaborating Agencies: Italian Space Agency (ASI); Particle Physics and Astronomy Research Council (UK)
- Collaborating Institutions: Penn State, Mullard Space Science Laboratory, University of Leicester, Brera Observatory, ASI Data Center, Los Alamos National Laboratory, Sonoma State University and University of California, Berkeley
- Contractors: General Dynamics, Swales Aerospace, South West Research Institute, Omnitron; EV Products
- Team info: Neil Gehrels (Principal Investigator), Joe Dezio (Project Manager), Nicholas White (Science Working Group Chair), John Nousek (Mission Director)
- Launch Vehicle Provider: The Boeing Company, Huntington Beach, Calif.
- Launch Vehicle/Operations: Kennedy Space Center, Florida.
- Launch Vehicle: Delta 7320 rocket
- Launch Site: Cape Canaveral Air Force Station, Florida.
- Launch Date and Time Date: November 17, 2004
- Lifetime: 2 years minimum
- Burst detection rate: >100/yr
- Spacecraft Dimensions (deployed on orbit): 18.5 ft H x 17.75 ft W
- Orbit inclination : 20 degree inclination, 600 kilometer altitude
- Spacecraft Separation: L+1 hour and 20 minutes
- First Acquisition of Signal: After spacecraft separation, TDRSS Contact is 1 minute and 13 seconds. Malindi Ground Station Contact is 54 minutes after the spacecraft separates
- In-Orbit Check-out: 45 days
- Mission Management: Goddard Space Flight Center, Greenbelt, Md.
- Ground segment, ASI Luigi Broglio Space Center, Malindi, Kenya



## Swift Mission Overview

NASA's Swift mission is a first-of-its-kind multi-wavelength observatory dedicated to the study of gamma-ray burst (GRB) science. Its three instruments will work together to observe GRBs and afterglows in the gamma-ray, X-ray, ultraviolet, and optical wavebands. The main mission objectives for Swift are to:

- Determine the origin of gamma-ray bursts.
- Classify gamma-ray bursts and search for new types.
- Determine how the explosion develops.
- Use gamma-ray bursts to study the early Universe.
- Perform the first sensitive hard X-ray survey of the sky.

During its mission lasting at least two years, Swift is expected to observe more than 200 bursts with a sensitivity about three times fainter than the BATSE detector aboard the Compton Gamma-Ray Observatory. Swift's Burst Alert Telescope will detect and acquire high-precision locations for gamma-ray bursts and then relay a 1-4 arc-minute position estimate to the ground within 20 seconds. After the initial burst detection, the spacecraft will autonomously and "swiftly" (approximately 20 to 75 seconds) reorient itself to bring the burst location within the field of view of the sensitive narrow-field X-ray and UV/optical telescopes to observe the afterglow. Swift measurements will be of great interest to the astronomical community, and all data products will be available to the public via the Internet as soon as they are processed. The Swift mission will represent the most comprehensive study of GRB afterglows to date.

Swift is part of NASA's medium explorer (MIDEX) program and is expected to enter into a low-Earth orbit on a Delta 7320 rocket in November 17, 2004. The hardware is being developed by an international team from the United States, the United Kingdom and Italy, with additional scientific involvement in Germany, Japan and France.

### Why Study Gamma Ray Bursts (GRBs)?

Gamma-ray bursts (GRBs) are the most powerful explosions the Universe has seen since the Big Bang. They are seen approximately once per day and are brief, but intense, flashes of gamma radiation. They come from all different directions of the sky and last from a few milliseconds to a few hundred seconds. So far scientists do not know what causes them. Do they signal the birth of a black hole in a massive stellar explosion? Are they the product of the collision of two neutron stars? Or is it some other exotic phenomenon that causes these bursts?

As the brightest sources that scientists observe, GRBs can be used to study the distant Universe. There is great hope that GRBs can show when the first stars were formed and what the gas and dust content of the Universe was at early times.

With Swift, scientists will now have a tool dedicated to answering these questions and solving the gamma-ray burst mystery. Its three instruments will give scientists the ability to scrutinize gamma-ray bursts like never before. Within seconds of detecting a burst, Swift will relay a burst's location to ground stations, allowing both ground-based and space-based telescopes around the world the opportunity to observe the burst's afterglow.



## Detailed Scientific Objectives

In its identification and analysis of over 100 gamma-ray bursts a year, Swift has several key scientific objectives. These include obtaining a deeper understanding of the GRB explosion and its interaction with the surrounding medium and using the intense radiation from the blast to probe the early universe.

The BATSE instrument aboard NASA's Compton Gamma-Ray Observatory in the 1990s opened wide the field of GRB investigation. BATSE, short for the Burst and Transient Source Experiment, made it clear that GRBs come to us from all directions and hinted that they come from cosmological distances (an appreciable fraction of the size of the universe). All told, BATSE detected over 2,700 GRBs.

Then in 1997 a small Italian satellite called BeppoSAX discovered that GRBs glow in X-ray, radio and optical light for hours and days after the initial flash, a phenomenon called the afterglow. Scientists could determine distances to the bursts by studying the lingering afterglow, and this revealed that GRBs are indeed cosmological in origin.

In 2000, NASA launched a satellite built by the Massachusetts Institute of Technology called HETE-2, the High-Energy Transient Explorer, dedicated to the GRB mystery. HETE-2 is still active today, and one of its landmark findings has been that at least some GRBs have their origin in massive star explosions that may ultimately form a black hole. Thus, there is the intriguing hint that some GRBs simultaneously signal both star death and black hole birth.

NASA's Swift mission is designed to respond to GRBs faster than any satellite that has come before. Swift has three instruments: one to detect a GRB and to provide a good approximation of its location within seconds; and two instruments to pinpoint the location and to study the burst afterglow in X-ray, ultraviolet and optical light. This unprecedented capability will allow astronomers to pursue a number of important scientific objectives:

*Swift will determine what causes GRBs and whether there are different kinds of GRBs.*

We now know that some GRBs arise from the explosion of massive stars. But each GRB is a little different, leading scientists to speculate that there may be several different types of progenitors. For example, some bursts last only for a few milliseconds while others last over a minute. The bulk of the GRBs seem to last between two and ten seconds, yet characteristics in their afterglow light differ. Aside from star explosions, some GRBs, in theory, may erupt from spectacular mergers, such as collisions between two neutron stars or two black holes. Some theorists speculate that a burst of Hawking radiation, signaling the complete evaporation of a black hole, could resemble a GRB. In these scenarios, scientists expect the burst to last less than two seconds. Interestingly, scientists have only detected afterglows from long bursts, longer than two seconds; and it is from this analysis that we can say that some longer bursts originate from massive star explosions. Detecting the afterglow of a short burst, if it exists, may reveal their nature.

⇒ *To address these questions, Swift will:*

- Observe hundreds of GRBs and afterglows.
- Detect bursts shorter, longer and up to three times fainter than those detected by BATSE.
- Identify the galaxies where the GRBs occur (called the host galaxies) and, by obtaining a precise arcsecond position, locate GRBs relative to the host galaxy. Swift will determine if the bursts always occur in star forming (and star dying) regions.

- Measure the redshift distribution (a distance measurement) of detected bursts and see how features such as energy and luminosity relate to distance.
- Analyze the local environment of GRBs by determining how dusty (or clean) the region is. Dust is the hallmark of star formation.

*Determine how the explosion blast wave evolves and interacts with its surroundings.*

Gamma-ray bursts are the most powerful explosions known in the Universe, second only to the Big Bang. The energies involved are clearly far greater than anything that can be reproduced in a laboratory. Thus, each GRB is a “cosmic laboratory” that can reveal new insights into nuclear and fundamental physics. The powerful blast wave plows the interstellar medium, with some of its debris accelerated to near light speed. This blast wave heats the surrounding gas to ultrahigh temperatures and, perhaps, triggers new star formation. It is this blast wave’s interaction with itself and the surrounding medium, in fact, that creates the gamma rays that we ultimately see. Yet what is the extent of this blast wave, and how wide is the beam of gamma rays?

⇒ *To address these questions, Swift will:*

- Perform detailed multiwavelength observations starting immediately after the burst.
- Monitor the afterglow frequently for days after the event at various multiwavelengths to reconstruct the evolution of the blast wave.
- Search for X-ray line and edge features that are indicative of the elemental composition and structure of the blast wave.

*Determine the GRB connection to the early Universe.*

Some theorists suggest that a small portion of GRBs may originate the first generation of stars in the Universe. These stars are thought to be upwards of 100 to 1,000 times more massive than our Sun, far more massive than stars today. These stars would contain only hydrogen and helium from the Big Bang and not heavier elements created in subsequent generations of stars. If such stars existed, they surely would have died with a resounding explosion like a GRB. Swift, through its study of these ancient bursts, could theoretically map out early star formation. No current telescope is powerful enough to see these first stars. Swift will see a number of distant GRBs, and each one will have traveled for billions of light years, illuminating its path along the way.

⇒ *In this regard, Swift will:*

- Use GRBs as high-redshift (long-distance) beacons by studying their optical, ultraviolet and X-ray afterglow and providing precise positions for follow-up observations by powerful ground-based telescopes.
- Use X-ray absorption to probe the intergalactic and cluster medium. That is, scientists can ascertain the contents of so-called empty (and optically dark) space by studying the X-ray light from a GRB afterglow that doesn’t reach us, blocked by invisible gas and dust.
- Measure the Universe’s star formation rate out to greater distances than what is currently known.
- Measure the “Lyman-alpha forest.” This is the sum of absorption lines seen in the optical spectra of quasars and other distant galaxies, essentially revealing the Universe’s web-like structure of chains of galaxies and galaxy clusters.

### *Survey the hard X-ray sky*

When Swift isn't detecting and analyzing bursts it will conduct a survey of the X-ray sky. The X-ray waveband comprises a wide chunk of the electromagnetic spectrum, far wider, for example, than the region we call optical light. Swift will concentrate on the "hard" or high-energy X-rays (which some scientists call soft gamma rays). This all-sky survey will be 20 times more sensitive than previous measurements. Scientists expect that Swift's enhanced sensitivity relative to earlier surveys will uncover over 400 new supermassive black holes that are obscured at softer X-ray energies.

### **A Medium-class Explorer Mission**

The purpose of the Explorers Program is to allow for frequent, high quality space science investigations. The MIDEEX Program is managed by the Goddard Space Flight Center in Greenbelt, Md.

## Swift Mission Themes

Swift will study the most energetic explosions in the Universe, observing matter and energy under extreme conditions that cannot be replicated on Earth. These explosions can be used to illuminate the conditions in the early Universe and appear to mark the fiery birth cries of black holes.

### 1. The most energetic explosions in the Universe

- GRBs are among the most puzzling and intriguing astronomical phenomena found in modern times. At distances of billions of light years, a GRB emits energy that is more than a hundred billion ( $10^{11}$ ) times the energy emitted by our Sun over an entire year.
- Swift uses a complement of three instruments to study GRBs and their afterglows. After an initial detection of a GRB using the wide-field Burst Alert Telescope (BAT), the observatory maneuvers “swiftly” to focus the narrow field instruments (XRT and UVOT) onto the burst and also “swiftly” relays the position of the burst to the ground for use by observers worldwide.
- Swift will determine the locations of GRBs within host galaxies, the distances to these galaxies, and characteristics of the environment surrounding the bursts.
- Swift will study the afterglow to determine how the blast wave interacts with its surroundings, and will measure properties of matter and energy under extreme conditions that cannot be replicated on Earth.
- Nature is full of surprises and Swift may reveal many secrets about our Universe, even in areas where we believe we have a firm understanding.

### 2. GRBs may signal the formation of black holes

- There appear to be two different types of GRBs, differentiated by their durations and energy properties. In both cases, it is believed that the GRBs signal the formation of a black hole.
- Afterglows have only been detected from longer GRBs. There is some evidence that a special type of supernova is associated with longer GRBs. In this “hypernova,” a very massive star collapses directly into a black hole.
- Shorter GRBs have been theorized to result from a merger of two neutron stars or other similar objects. A black hole would be the end product of such a merger. Swift observations will test this theory.

### 3. GRBs can shine light through the early Universe

- Swift may detect GRBs at distances farther than the most distant galaxies now observed.
- As GRBs are the most luminous events in the Universe, they act like beacons shining through everything along their paths, including the gas between galaxies and within galaxies along the line of sight.
- By measuring the distances to hundreds of GRBs, Swift will directly study how GRBs evolve with cosmic time. It has been predicted that the most distant GRBs (redshift greater than about 15) may emanate from the very first generation of stars.

## Swift Instrument Descriptions

The Swift observatory comprises three instruments, which work in tandem to provide rapid identification and multi-wavelength follow-up of GRBs and their afterglows. Within 20 to 75 seconds of a detected GRB, the observatory will slew autonomously so that the fields-of-view of the pointed instruments overlap the location of the burst. The afterglows will be monitored over their durations, and the data will be rapidly disseminated to the public.

### **Burst Alert Telescope (BAT):**

The BAT has two features key to catching gamma ray bursts. It has a large field of view, which means that it can observe large regions of the sky all at once. The BAT is also a coded aperture instrument, which enables it to locate the position in the sky where a burst originates. The BAT will detect and locate, on average several gamma ray bursts per week. The BAT may confirm or refute existing theories about differing types of gamma ray bursts and find new properties as well. The BAT was produced by the Laboratory for High Energy Astrophysics at NASA Goddard Space Flight Center with science flight software developed by the Los Alamos National Laboratory.

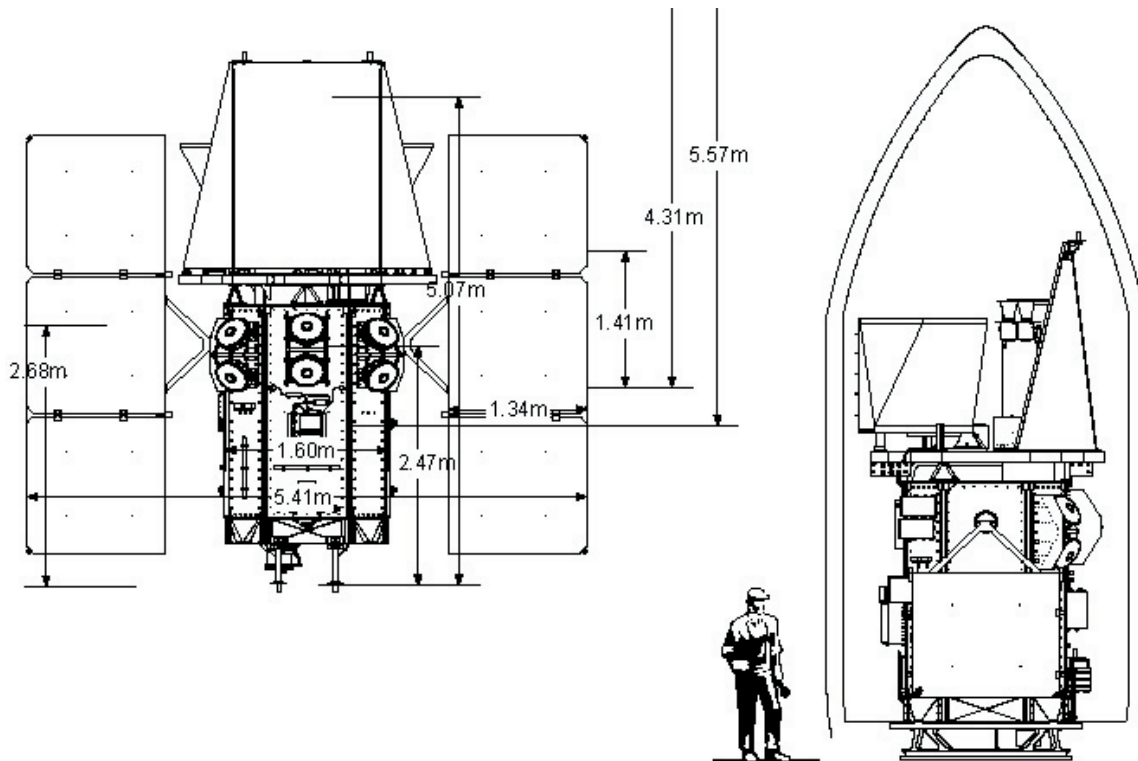
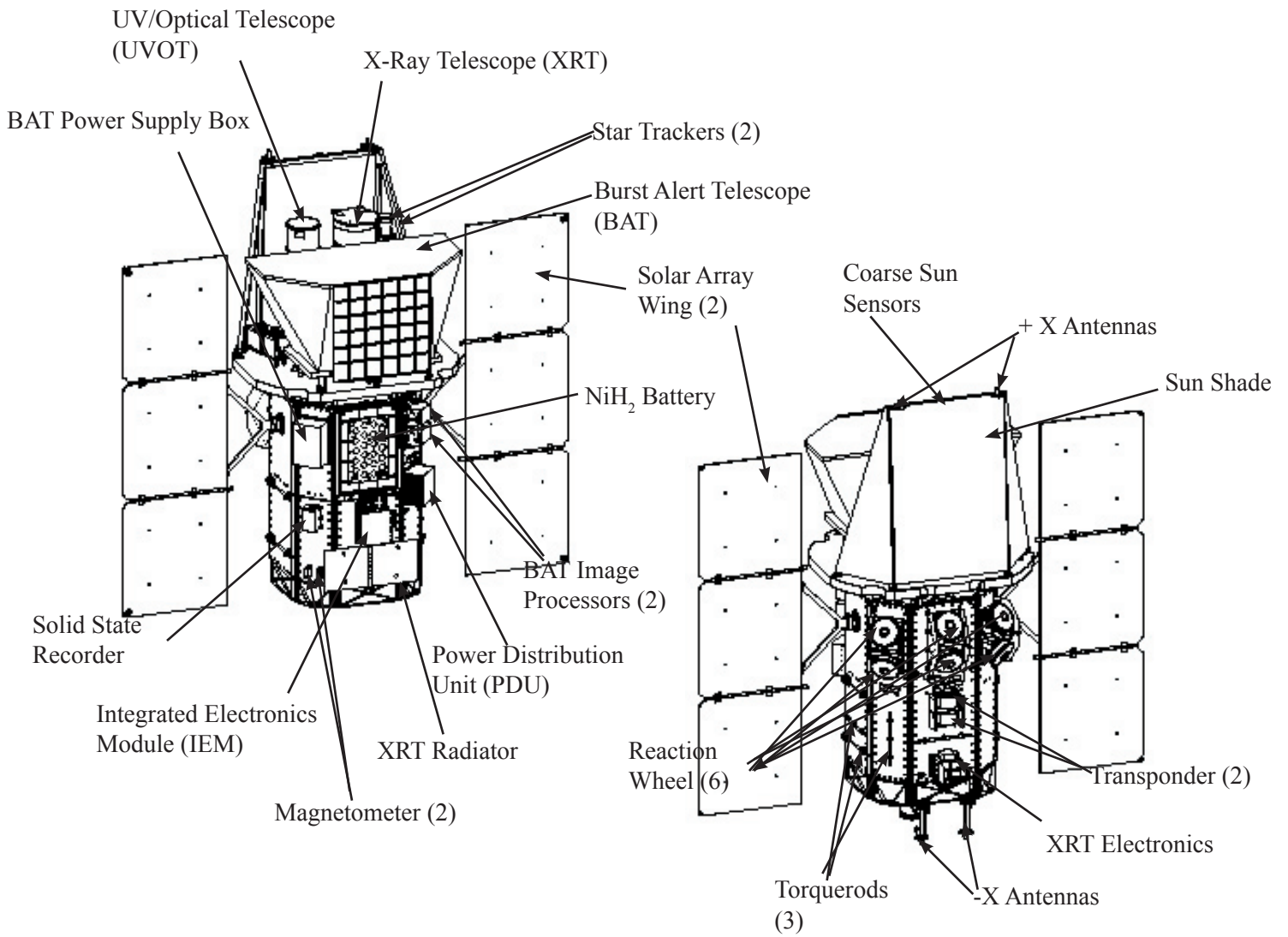
### **X-ray Telescope (XRT):**

The XRT provides even more accurate burst locations than does the BAT. The XRT captures the spectrum, or distribution of X-ray energies, in a given burst. Long, detailed X-ray observations of gamma-ray burst afterglows have been difficult to obtain because the few X-ray telescopes in operation have not been able to point in the right direction until hours or days after the burst. The swift repointing capability of the XRT ensures that most bursts caught by Swift's BAT will be studied in X-ray light. The XRT is a joint product of Penn State University, the Brera Astronomical Observatory in Italy, and the University of Leicester in the UK and uses technologies from XMM/EPIC and JET-X heritage.

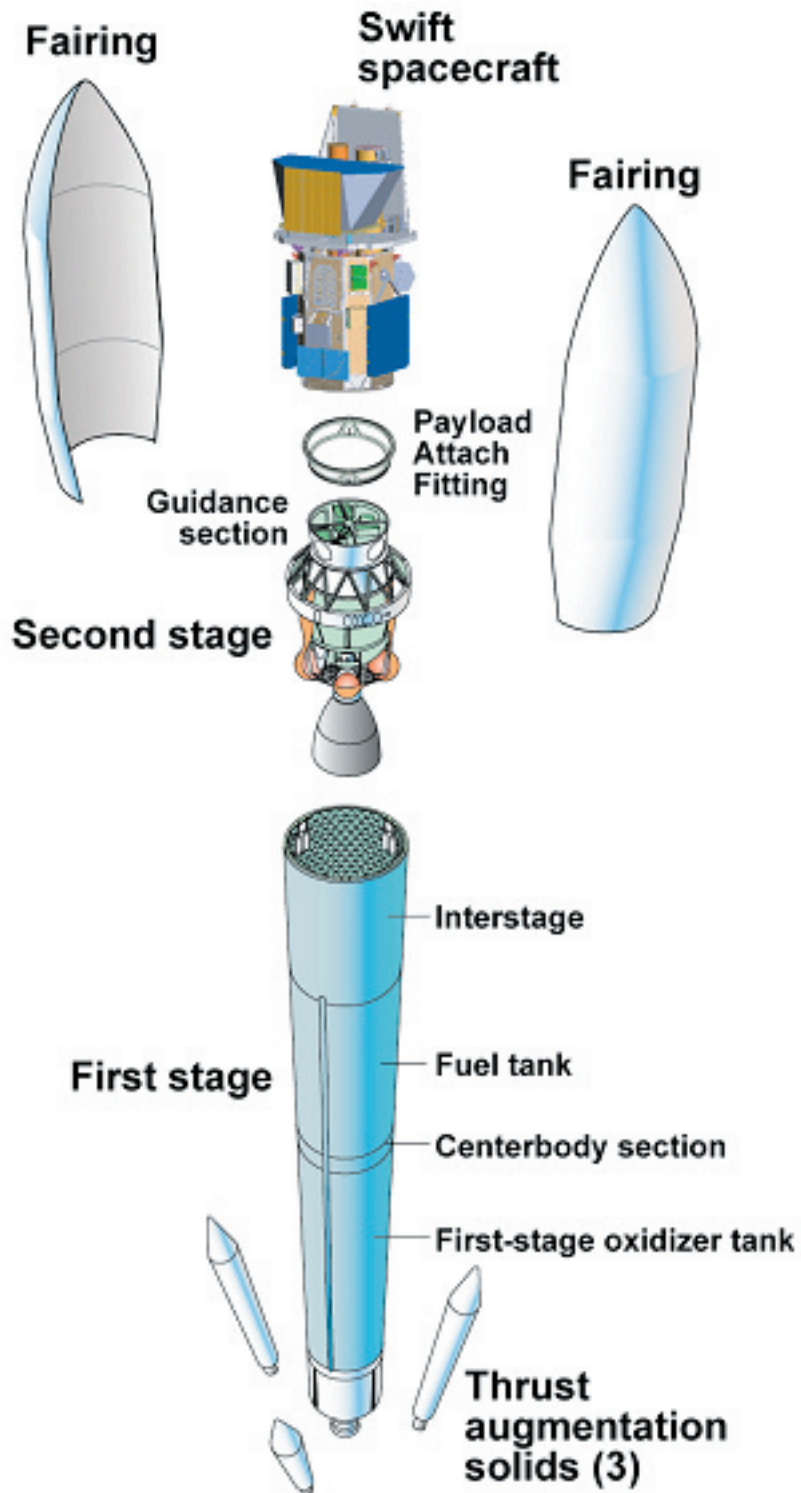
### **Ultraviolet/Optical Telescope (UVOT):**

The UVOT will capture the ultraviolet and optical properties of the gamma-ray burst afterglow. It provides the most accurate onboard determination of the burst position ( $\leq 1$  arcsecond). The UVOT is a 30-centimeter telescope with intensified CCD detectors and is nearly identical to an instrument now being flown on the European Space Agency's XMM-Newton mission. The UVOT is as sensitive as a four-meter optical ground-based telescope. Together, the XRT and UVOT will determine the distances to bursts and collect information about the bursts' host galaxies. The UVOT is a joint product of Penn State University and the Mullard Space Science Laboratory in the UK and is a development based on the XMM Optical Mirror. The data will be sent to the ground via NASA's TDRSS relay satellites for quick-look data and via the Italian Space Agency's Malindi ground station in Kenya for the bulk of the data.

# Swift Satellite Schematic



# Swift Delta Configuration



## Swift Mission Participants: Institutional Responsibilities

<i>Responsibilities</i>	<i>Lead Institution</i>
Principal Investigator, Mission Management	Goddard Space Flight Center (GSFC)
Spacecraft	General Dynamics
BAT Instrument Management, Hardware On-board GRB Software Other Flight Software	GSFC Los Alamos National Laboratory GSFC
XRT Instrument Management, Electronics, Software	Penn State University (flight software) ASI (ground software)
Detector System Mirrors Calibration	University of Leicester Osservatorio Astronomico di Brera
Data Analysis Software	Max Planck Institut für Extraterrestrische Physik ASI Science Data Center
UVOT Instrument Management, Electronics Instrument Development Software	Penn State University Mullard Space Science Laboratory GSFC (ground software) Penn State/MSSL (flight software)
Mission Integration and Test	General Dynamics/GSFC
Ground System Management	GSFC
Ground Station	ASI space center Malindi, Kenya
Mission Operations Center	Penn State University
Science Center	GSFC
Data Centers	GSFC, ASI Science Data Center / Osservatorio Astronomico di Brera , University of Leicester
GRB Follow-up	University of California, Berkeley
Education/Public Outreach	Sonoma State University



## Swift Mission Timeline

<i>Days After Launch</i>	<i>Spacecraft or Instrument Event</i>
1	Malindi (Ground Station) acquisition; access S/C State of Health
2	Check S/C clock, adjust (daily, from now on)
3	XRT: Power up electronics & telescope; open sun shutter
4	Begin spacecraft slew testing (continue through Day 16) FoM*: begin logic checks and diagnostics BAT: begin powering up electronics
5	UVOT: begin powering up electronics
6	BAT: begin powering up instrument in parts, with testing; continue through Day 20
STBS	BAT: early trigger tests (before full instrument powered up); sometime in vicinity of Day 14
17	FoM: begin further testing - first Pre-Planned Sci. Timeline tests
21	BAT: end-to-end test (now fully powered on)
22	XRT: open door
23	XRT: “first light” image
24	UVOT: open door
28	XRT: in AUTO state (no longer MANUAL operations)
30	Observatory End-to-End Checkout
34	UVOT: “First Light” Exposure

\* FoM = Figure of Merit processor in the BAT that determines if the spacecraft should re-point toward a particular GRB

## Swift Mission Operations

The Swift Mission Operations Center (MOC), located at Penn State University in University Park, Pennsylvania, is responsible for operating and controlling the satellite and for receiving, and distributing data from Swift about gamma-ray bursts. MOC scientists also are responsible for planning Swift observations, for commanding and uploading software to the satellite, for verifying the health and safety of the satellite and its instruments, and for quickly reviewing the gamma-ray-burst data as it arrives. The MOC receives almost all of Swift's data--in the range of six thousand million bytes per day--via a transmission station in Kenya maintained by the Italian Space Agency. A small portion of Swift's data--about fifty thousand bytes per day--is delivered via TDRSS (Tracking and Data Relay Satellite System) simultaneously to the MOC at Penn State and to the Goddard Space Flight Center in Maryland, which shares the data with astronomers worldwide through Swift's gamma-ray-burst coordinates network (GCN). The Penn State team at the MOC also built and tested Swift's X-ray and UV/optical telescopes, along with the Swift partners at the University of Leicester and Mullard Space Science Laboratory in England and the Brera Observatory in Italy.

## Swift Data Processing

Swift Data processing is performed at the Swift Data Center (SDC) at GSFC. The SDC is responsible for processing of Swift data, turning spacecraft telemetry into higher level science products and data files for the end user. The SDC then distributes these products to the science team and the community. After one week, the processed data and science products are delivered by the SDC to the GSFC for long term archiving. Data will also be sent to the Data Center at the University of Leicester and the data center in Italy. The ASI Data Center (ASDC) is also the mirror site of the data. The SDC will create and maintain a database of results for community access through the World Wide Web. The SDC is based on similar efforts for the ROSAT, ASCA, and RXTE missions.

## Swift Mission Participants: Key Personnel

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# Gamma-ray Burst Primer

## The Collapsar - Fireball Model

Gamma-ray bursts -- shining hundreds of times brighter than a supernova and as bright as a million trillion suns -- are quick bursts of gamma-ray photons that satellites detect almost daily in wholly random directions of the sky. The bursts last from a few milliseconds to roughly 100 seconds. The short-duration bursts are defined as those lasting less than 2 seconds, while long-duration bursts last more than 2 seconds. These bursts are often followed by an afterglow, a secondary burst of light in the form of X rays, visible light, and radio waves. The afterglow can persist for hours, days, or even weeks.

What causes these bursts? A burst detected on October 4, 2002, called GRB 021004, was particularly long, lasting nearly 100 seconds. GRB 021004 has become the best-studied burst to date. Observations strongly suggested that this burst was created by a collapsar -- a massive Wolf-Rayet star that collapses onto itself during an especially powerful supernova, dubbed a hypernova.

Theorists have proposed that long-duration gamma-ray bursts result from a collapsar. When such a star, with the mass at least 20 to 30 times the sun, depletes its nuclear fuel, it has no outward radiation pressure to support its bulk. The core of the star -- containing the mass of several suns -- implodes (collapses) into a black hole, while most of the star's bulk explodes into the surrounding interstellar medium. We recognize the explosion as the supernova event. The gamma-ray burst, however, occurs before the star breaks apart, set in motion by the newly formed black hole.

Theorists suggest that the black hole immediately begins to pull in more stellar material; and very quickly a disk of material called an accretion disk forms, with the inner portion of the disk spinning around the black hole at near light speed. Rotating, conducting fluids create a magnetic field, and this accretion disk is no exception. Yet because the inner portion of the accretion disk is rotating more quickly than the outer portion, the magnetic field lines twist violently. This causes a jet of material to blast outward at almost the speed of light perpendicularly to the accretion disk. The jet contains matter and antimatter in the form of electrons, positrons and protons.

This is the collapsar model of gamma-ray bursts: the collapse of the stellar core into a black hole. But it is only the first step in making a gamma-ray burst. Step two is the relativistic fireball shock model.

Because this jet of material moves at nearly the speed of light, relativistic effects (referring to Einstein's theory of special relativity) take over. The jet is the "fireball," although it really is more like a fire hose. The fireball behaves as a shock wave as it races outward, plowing into and sweeping up matter in its way. Inside the fireball, pressure, density and temperature vary, resulting in a series of internal shock waves within the fireball as faster moving blobs of material overtake slower moving blobs. (From the frame of reference of the faster blobs, though, the slower blobs appear to be moving at relativistic speeds backwards through the plasma.)

Gamma rays are produced as a result of the collisions of blobs of matter. But the fireball medium does not allow the light to escape until it has cooled just enough to become transparent -- at which point the light particles race outward in the direction of motion of the jet, just ahead of the lead shock front. From our perspective on Earth, the photons first detected have been accelerated toward us, resulting in a "blue-shift" to the shortest frequencies and highest energies possible (i.e. gamma rays). This is the gamma-ray burst.

The afterglow results when material in the fireball plows into the material in the interstellar medium to create a wide array of less energetic light. Initially X rays result, but as the blobs of matter bump into each other, they lose their kinetic energy and the resulting energies decrease -- through visible light and eventually into radio waves. In theory, the afterglow can persist for months as the energies gradually shift to lower frequencies.

### History Of Gamma-Ray Burst Studies

**October 1963:** The U.S. Air Force launches the first in a series of “Vela” satellites carrying X-ray, gamma-ray and neutron detectors in order to monitor nuclear testing by the Soviet Union or other nations in violation of the just-signed nuclear test ban treaty.

**July 2, 1967:** The Vela 4a,b satellite makes first-ever observation of a gamma-ray burst. The actual determination would come two years later in 1969. The results would not be declassified and published until 1973.

**March 14, 1971:** NASA launches the IMP 6 satellite. Aboard the satellite is a gamma-ray detector. Although the main purpose of the instruments was not to detect for gamma-ray bursts (GRB), it nevertheless inadvertently observes them while monitoring solar flares.

**September 1971:** The Seventh Orbiting Solar Observatory (OSO-7) is launched. It carries an X-ray telescope designed to measure hard (very energetic) X-rays from sources across the sky. OSO-7 also includes a gamma-ray monitor.

**1972-1973:** Los Alamos scientists analyze various Vela gamma-ray events. They conclude that gamma-ray bursts are indeed “of cosmic origin.” They publish their findings concerning 16 bursts as observed by Vela 5a,b and Vela 6a,b between July 1969 and July 1972 in the *Astrophysical Journal* in 1973.

**1974:** Data from Soviet Konus satellites is published, confirming the detection of these bursts of gamma rays.

**1976:** The start of the Interplanetary Network (IPN), a set of gamma-ray detectors placed on spacecraft studying the Sun and planets. These detectors work in unison to locate gamma-ray bursts through a process

of triangulation. By localizing the sources of GRBs to a few arc minutes, the IPN shows that these sources are not known sources of interest, such as X-ray emitters. The IPN continues today.

**March 5, 1979:** An unusual gamma-ray transient is found, later localized to the N49 supernova remnant in the LMC. This causes a controversy that lasts for over a decade: One side maintains accidental coincidence (the thought was that GRBs could not come from anything as distant as the LMC galaxy); while the other maintains two classes of sources exist, and that this is a separate one from GRBs. Later study of Soft Gamma Repeaters by the Japan-U.S. ASCA satellite proves the latter to be correct. (And, GRBs do come from very distant sources.)

**April 5, 1991:** NASA launches the Compton Gamma Ray Observatory. Among its payload is the Burst And Transient Source Experiment (BATSE) instrument, which detects over 2,700 gamma-ray bursts in nine years. BATSE data proves that gamma-ray bursts are uniformly distributed across the sky, not concentrated along the plane of the Milky Way. This means that gamma-ray bursts originate far outside of the Milky Way galaxy. This disproves the galactic neutron star theory. It also suggests that gamma-ray bursts had mind-boggling energies associated with them in order to be detectable across the entire observable universe. This marks a paradigm shift.

**December 30, 1995:** NASA launches the Rossi X-ray Timing Explorer, designed to study how the emission lines of X-ray emitting sources change with time. This will be used subsequently to study the X-ray afterglow of gamma-ray bursts.



**April 30, 1996:** The BeppoSAX satellite, a joint collaboration of the Italian Space Agency and the Netherlands Space Agency, is launched.

**February 28, 1997:** Using BeppoSAX, astronomers looking at GRB979228 detect an X-ray afterglow associated with a gamma-ray burst for the first time. This begins the era of studying GRB afterglows. This made it possible to measure a redshift distance, thus ruling out the theory that GRBs all originate in our galaxy.

**January 23, 1999:** The afterglow of GRB990123 is detected within seconds of the initial burst. Based on careful analysis, astronomers determined that the energy is channeled (beamed) in narrow jets and that we detect GRBs only if the jet is aimed along our line of sight. The energy output of GRB990123 is put at  $10^{43}$  watts -- 1,000 times more luminous than quasars and one hundred quadrillion times more luminous than the Sun.

**July 5, 1999:** GRB990705 is detected. Analysis of the emission lines from the afterglow suggests an iron-absorption feature that is characteristic of a supernova.

**December 12, 1999:** Observations of emission lines from GRB991216 afterglow detected by the ASCA and Chandra X-ray satellites reveal iron lines. This helped to pinpoint a distance to the burst.

**January 21, 2000:** Peter Meszaros, Bohdan Paczynski and Martin Rees are each awarded the Bruno Rossi Prize by the High Energy Astrophysics Division of the American Astronomical Society for their work on gamma-ray bursts.

**March 26, 2000:** BATSE detects its final burst, number 2,704.

**October 9, 2000:** NASA's High Energy Transient Explorer (HETE) is launched. The international, MIT-built HETE was designed

to detect and rapidly pinpoint the location of gamma-ray bursts.

**December 11, 2001:** GRB 011211 is detected. The European Space Agency's XMM-Newton satellite finds evidence of silicon, sulfur, argon, and other elements in the shell of gas surrounding the burst. Such elements are associated with the GRB collapsar model, in which a massive star implodes to form a black hole and a supernova.

**October 4, 2002:** HETE detects a burst observed so quickly by other telescopes that scientists find evidence of the death of a massive star and the birth of what appears to be a black hole in its place.

**October 17, 2002:** The European Space Agency launches INTEGRAL, a gamma-ray observatory containing a burst detector. INTEGRAL detects several bursts during its first months of operation.

**December 23, 2002:** HETE detects the first "dark" gamma-ray burst with an afterglow. Such bursts, accounting for roughly half of all GRBs, were thought to be devoid of optical afterglows. This afterglow disappears within 2 hours -- meaning that if the afterglow hadn't been detected as quickly as it had, this GRB would've been labeled "dark". Perhaps no burst is truly dark if observed fast enough.

**March 19, 2003:** NASA announces compelling evidence that long-duration gamma-ray bursts (lasting over 10 seconds) form from the death of massive stars and simultaneous creation of black holes.

**November 17, 2004:** NASA's Swift satellite will be launched. Swift carries instruments designed to observe GRBs and their afterglow in X-ray, ultraviolet and optical light wavelengths.

**Planned for 2007:** The Gamma Ray Large Area Space Telescope (GLAST) will carry an instrument to detect gamma-ray bursts with photons thousands of times more energetic than what Swift detects.

## Glossary

**Afterglow:** The less-energetic forms of electromagnetic radiation, including X rays, optical light and radio waves, that often follow the initial burst of gamma rays in a gamma-ray burst. The afterglow can persist for days to weeks, gradually dissipating with time. The BeppoSAX satellite discovered the afterglow phenomenon in 1997.

**BeppoSAX:** An Italian X-ray satellite mission with Dutch participation that was launched on April 30, 1996. BeppoSAX was active for six years observing a wide range of celestial X-ray sources. BeppoSAX discovered the afterglow phenomenon from a burst on February 28, 1997, and also helped find more precise locations of many gamma-ray bursts.

**Binary merger theory:** A theory on the origin of gamma-ray bursts, in which two compact stellar objects merge. The objects could be neutron stars or stellar black holes, and the merger would result in a new, single black hole.

**Black hole:** An object so dense that its escape velocity exceeds the speed of light. Theoretically, the object collapses to a single point of infinite density, called a singularity. Light or matter that crosses the theoretical border of the black hole, called the event horizon, cannot return.

There are two main classes of black holes. A stellar black hole is the core remains of an imploded massive star. The Milky Way Galaxy is likely home to thousands of stellar black holes, with masses ranging from 3 to 20 solar masses. A supermassive black hole has a mass of millions to billions of solar masses confined to a region no larger than our Solar System. These likely exist at the center of most galaxies and are thought to power quasars. A new class of intermediate-mass black holes is now emerging.

**BATSE:** The Burst and Transient Source Experiment aboard the Compton Gamma Ray Observatory. This instrument detected over 2,700 gamma-ray bursts and helped astronomers determine that these bursts appear from all directions and originate billions of light years away.

**Compact object:** An extremely dense stellar object, namely a black hole, neutron star, or white dwarf. An observer sees such an object as a point, too small to resolve.

**Compton Gamma Ray Observatory:** One of NASA's four Great Observatories, launched in April 1991. The satellite, no longer in orbit, lasted nine years, and its four main instruments discovered hundreds of exotic objects radiating in gamma rays. Compton's BATSE instrument detected over 2,700 gamma-ray bursts.

**Dark gamma-ray burst:** Long-duration gamma-ray bursts that leave little or no afterglow, comprising about 30 percent of all bursts. Such bursts are thought to be dark because (a) there is a lack of sufficient gas and dust in the interstellar medium to create the afterglow; or (b) the burst is so enshrouded in dust that only gamma rays can escape.

**Fireball shock model:** A model describing the behavior of an expanding fireball associated with a gamma-ray burst. The model explains how the fireball creates external and internal shock waves that propagate both in the forward and reverse directions. It also predicts the existence of the gamma-ray burst afterglow.



**Gamma rays:** The most energetic form of electromagnetic radiation, with extremely short wavelengths and high frequencies. The Earth's atmosphere blocks most celestial gamma rays from reaching the Earth's surface. The most energetic gamma rays create secondary particles in the Earth's atmosphere, which can be detected from the ground. Other gamma rays are detected from space.

**Gamma-ray burst (GRB):** A short-lived, extremely intense burst of gamma rays likely signaling the birth of a black hole. GRBs are common yet enigmatic and random, lasting from only a few milliseconds to about 100 seconds. GRBs are considered "short" if under two seconds and "long" if over two seconds. Most GRBs likely originate billions of light years away. GRBs are named by date; GRB 021004, for example, was detected on October 4, 2002.

**Hard X ray:** Also called soft gamma rays, referring to gamma rays of lower energy.

**Hypernova:** A theorized supernova, or star explosion, involving a star approximately 100 solar masses. This could be one possible cause of a gamma-ray burst, providing 100 times the energy of a "regular" supernova.

**Long-duration burst:** Gamma-ray bursts lasting longer than 2 seconds. Most long-duration bursts last about 10 seconds, though some as long as 100 seconds. These are believed produced by the explosion of a massive star.

**Magnetar:** A neutron star with an incredibly strong magnetic field, thousands of times stronger than that of an ordinary neutron star and over a hundred trillion times stronger than that of the Earth or Sun. Magnetars were first theorized in 1992 and detected in 1998.

**Neutron star:** The collapsed, core remains of a massive star that exploded in a supernova event. Neutron stars are ultra-dense spheres, only 10 to 15 miles across yet containing more mass than our Sun. Neutron stars have a thin metallic crust, beneath which lies a superfluid of neutrons. Merging neutron stars might produce gamma-ray bursts.

**Photon:** A particle of light. As the carrier of electromagnetic radiation, this particle has zero mass and always moves, by definition, at the speed of light. Electromagnetic radiation with a certain wavelength (frequency) appears as visible light. The most energetic photons are called gamma rays.

**Pulsar:** A rapidly spinning neutron star. Such objects can spin thousands of times a second. The name derives from the fact that they appear to pulse regularly as they emit a range of electromagnetic radiation with a precision that rivals many of the best human-made clocks.

**Redshift:** An apparent shift toward longer wavelengths of the electromagnetic radiation (or, lower energies) emitted by an object moving away from the observer. Because the Universe is expanding, distant objects are rapidly moving away from the Earth and have large redshifts. Redshifts are used to measure distance and speed, analogous to Doppler radar.

**Shock wave:** A strong compression wave moving through a material medium where there is a sudden change in velocity, density, pressure, or temperature of the material. In the gamma-ray burst fireball model, the forward motion of the fireball creates a forward shock, while the bunching up of matter along the shock front creates a reverse shock that appears to propagate back through the fireball. The forward shock sweeps up material in the vicinity of a gamma-ray burst and slams it into material already in the interstellar medium. This collision forms the burst afterglow.



**Short-duration burst:** Gamma-ray bursts lasting less than 2 seconds. Such bursts are thought to result from the merger of two compact objects, such as a binary system containing neutron stars or black holes.

**Soft X rays:** Lower-energy X rays, also called extreme ultraviolet.

**Supernova:** The violent explosion of a massive star (at least 8 solar masses) that occurs when the star has exhausted its internal fuel supply. Without radiation pressure from nuclear fusion to support the mass of the star, the stellar core collapses while the outer shells explode outward. The core collapses into a neutron star or black hole. A supernova can outshine its host galaxy for several days.

**Transitional burst:** A rare category of gamma-ray bursts that have duration of about 2 to 3 seconds, placing them in between the short and long varieties.

**X-ray rich gamma-ray burst:** A type of gamma-ray burst in which more X rays are emitted than gamma rays. These account for 20 to 30 percent of the observed gamma-ray bursts. Some X-ray rich bursts produce no detectable gamma rays at all, just X rays. These are called X-ray bursts, and they are quite rare, perhaps originating as gamma-ray bursts so distant that their gamma-ray photons have redshifted to X-ray energies.