

The key design objectives for the ABWR were established during the development program. The key goals, all of which were achieved, are as follows:

- Design life of 60 years.
- Plant availability factor of 87% or greater.
- Less than one unplanned scram per year.
- 18 to 24-month refueling interval.
- Operating personnel radiation exposure limit <1 Sv/year.
- Reduced calculated core damage frequency by at least a factor of 10 over previous BWRs (goal <10⁻⁶/yr).
- Radwaste generation <100 m³/yr.
- 48-month construction schedule.
- 20% reduction in capital cost (\$/kWh) vs. previous 1100 MWe class BWRs.

Summary of the ABWR Key Features

A comparison of key features of the ABWR to the previous model, known as BWR/6, is shown in Table 2-1. The cutaway rendering of the ABWR plant (Figure 2-1) illustrates the general configuration of the plant for a single unit site in the U.S. Shown in the foreground is the Reactor Building, and in the background is the Turbine Building. Between them is located the Control Building.

An artist's rendering of the major systems and how they are inter-connected is shown in Figure 2-2. This shows the reactor, ECCS, containment, turbine equipment and the key auxiliary mechanical systems.

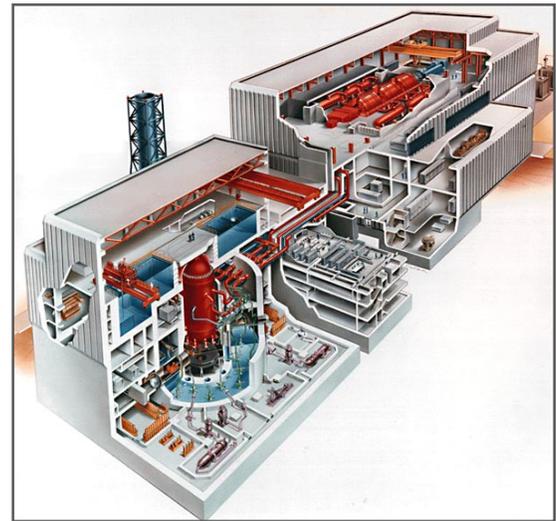


Figure 2-1. Cutaway Rendering of the ABWR

Safety Enhancement

Recognizing the desire for the continuous enhancement of safety, one of GE's goals for the ABWR was to reduce calculated core damage frequency by an order of magnitude relative to currently operating plants. The most important design feature contributing to this goal is the adoption of reactor internal pumps (RIPs), which are shown in Figure 2-3. These vessel-mounted pumps eliminate large, recirculation piping on the vessel, particularly involving penetrations below the top of the core elevation, and make possible a smaller Emergency Core Cooling System (ECCS) network to maintain core coverage during postulated loss-of-coolant events.

Advanced Boiling Water Reactor

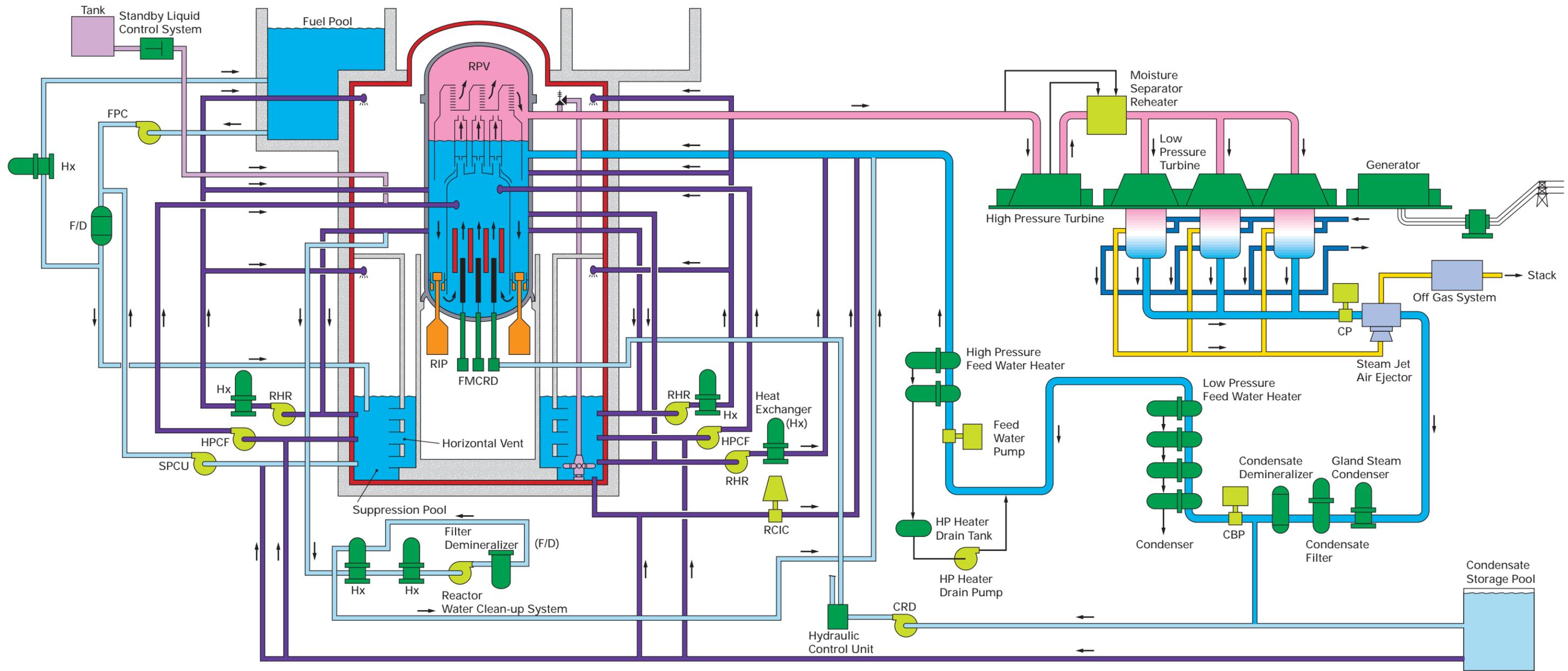


Figure 2-2. ABWR major systems.

| <i>Feature</i> | <i>ABWR</i> | <i>BWR/6</i> |
|----------------------------|--|---|
| Recirculation | Vessel-mounted reactor internal pumps | Two external loop Recirc system with jet pumps inside RPV |
| Control Rod Drives | Fine-motion CRDs | Locking piston CRDs |
| ECCS | 3-division ECCS | 2-division ECCS plus HPCS |
| Reactor Vessel | Extensive use of forged rings | Welded plate |
| Primary Containment | Advanced - compact, inerted | Mark III - large, low pressure, not inerted |
| Secondary Containment | Reactor Building | Shield, fuel, auxiliary & DG buildings |
| Control & Instrumentation | Digital, multiplexed, fiber optics, multiple channel | Analog, hardwired, single channel |
| Control Room | Operator task-based | System-based |
| Severe Accident Mitigation | Inerting, drywell flooding, containment venting | Not specifically addressed |
| Reactor Water Cleanup | 2%, sealless pumps in cold leg | 1%, pumps in hot leg |
| Offgas | Passive offgas with room-temperature charcoal | Active offgas with chilled charcoal filters |

Table 2-1. Comparison of Key ABWR Features to a BWR/6

The ABWR ECCS network was designed as a full three-division* system, with both a high and low pressure injection pump and heat removal capability in each division. For diversity, one of the systems, the Reactor Core Isolation Cooling (RCIC) System, includes a steam-driven, high pressure pump. Transient response was improved by designing three available high-pressure injection systems in addition to feedwater. The adoption of three on-site emergency diesel-generators to support core cooling and heat removal, as well as the addition of an on-site gas turbine-generator, reduces the potential for “station blackout” (SBO). The balanced ECCS system has less reliance on the Automatic Depressurization System

(ADS) function, since a single, motor-driven high pressure core flooder (HPCF) can maintain core safety for any postulated pipe break.

Response to anticipated transients without scram (ATWS) is improved by the adoption of fine-motion control rod drives (FMCRDs), which allow reactor

*The term *division* means that all systems and support systems necessary to complete the safety function are contained within the division, and that division is physically separated from other divisions to avoid any propagating failures, such as threats due to fire or flood.

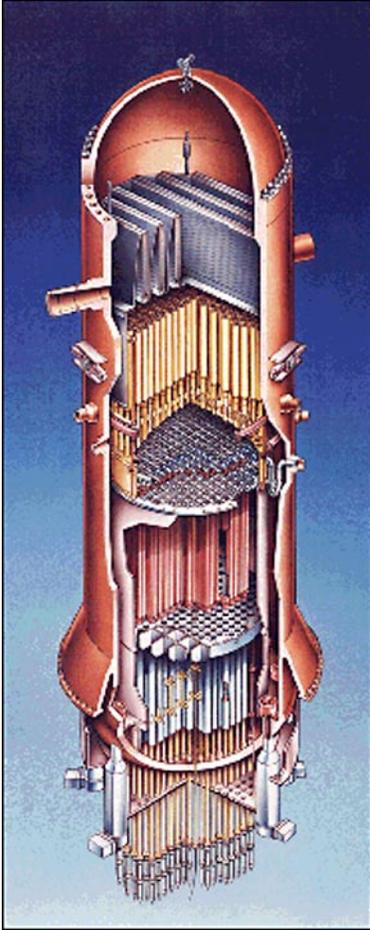


Figure 2-3. ABWR Reactor Pressure Vessel and Internals

shutdown either by hydraulic or electric insertion. In addition, the need for rapid operator action to mitigate an ATWS is avoided by automation of emergency procedures such as feedwater runback and Standby Liquid Control System (SLCS) injection.

Calculated core damage frequency is reduced by more than a factor of ten relative to the BWR/6 design. Furthermore, the ABWR also improved the capability to mitigate severe accidents, even though such events are extremely unlikely. Through nitrogen inerting,

containment integrity threats from hydrogen generation were eliminated. Sufficient spreading area in the lower drywell, together with a drywell flooding system, assures coolability of postulated core debris. Manual connections make it possible to use onsite or offsite water systems to maintain core cooling. Finally, to reduce potential offsite consequences, a passive, hard-piped wetwell vent, controlled by rupture disks, is designed to prevent catastrophic containment failure and provide maximum fission product “scrubbing”. The result of this design effort is that in the event of a severe accident, the whole body dose consequence at the calculated site boundary is less than 25 Rem. The probability of such an occurrence is calculated at the very low level of 10^{-9} /year. More information on this subject can be found in Chapter 10.

Improvements to Operation and Maintenance

With the goal of simplifying the utility’s burden of operation and maintenance (O&M) tasks, the design of every ABWR electrical and mechanical system, as well as the layout of equipment in the plant, is focused on improved O&M.

The reactor vessel is made of forged rings rather than welded plates. This eliminates 30% of the welds from the core beltline region, for which periodic in-service inspection is required. Since there are ten RIPs on four power buses, the ABWR’s recirculation system is quite robust. Pump speed is controlled by solid-state adjustable speed drives, eliminating the requirement for flow control valves and low-speed motor-generator sets. The wet motor design also eliminates rotating seals.

The FMCRDs permit a number of simplifications. First, scram discharge piping and scram discharge volumes (SDVs) were eliminated, since the hydraulic scram water is discharged into the reactor vessel. By supporting the drives directly from the core plate, shootout steel located below the reactor vessel to mitigate the rod ejection accident was eliminated. The number of hydraulic control units (HCUs) was reduced by connecting two drives to each HCU. The number of rods per gang was increased up to 26 rods, greatly improving reactor startup times. Finally, since there

are no organic seals, only two or three drives will be inspected per outage, rather than the 30 specified in most current plants.

It was possible to significantly downsize ECCS equipment as a result of eliminating large vessel nozzles below the top of the core. Capacity requirements are sized based on operating requirements—transient response and shutdown cooling—rather than on the need for large reflood capability. Inside the reactor vessel, core spray spargers were eliminated, since no postulated LOCA would lead to core uncover. For transient response, the initiation water levels for RCIC and HPCF were separated so that there is reduced duty on the equipment relative to earlier BWRs. There are three complete shutdown cooling loops, including dedicated vessel nozzles. Complex operating modes of the Residual Heat Removal (RHR) Systems, such as steam condensing, were eliminated. Finally, heat removal, in addition to core injection, was automated so that the operator no longer needs to choose which mode to perform during transients and accidents.

Lessons learned from operating experience were applied to the selection of ABWR materials. Stainless steel materials which qualified as resistant to intergranular stress corrosion cracking (IGSCC) were used. In areas of high neutron flux, materials were also specially selected for resistance to irradiation-assisted stress corrosion cracking (IASCC). Hydrogen Water Chemistry (HWC) is recommended for normal operation to further mitigate any potential for stress corrosion cracking.

The use of material producing radioactive cobalt was minimized. The condenser uses titanium tubing at sea water sites and stainless steel tubing for cooling tower sites. The use of stainless steel in applications that currently use carbon steel was expanded. Depleted Zinc Oxide is recommended to further control radiation buildup. These materials choices reduce plant-wide radiation levels and radwaste and will accommodate more stringent water chemistry requirements.

Also contributing to good reactor water chemistry is the increase of the Reactor Water Cleanup System (RWCU)

capacity to two percent. A more complete summary of materials and water chemistry considerations is given in Appendix B.

The Offgas System was simplified, reflecting lessons learned from operating experience. The charcoal beds are maintained at ambient temperature rather than refrigerated. The desiccant drier was eliminated.

The ABWR Reactor Building (including containment) was configured to simplify and reduce the O&M burden. Figure 2-4 illustrates some of the key design features of the ABWR containment. The containment itself is a reinforced concrete containment vessel (RCCV).

Within the containment itself, no equipment requires servicing during plant operation. The containment is significantly smaller than that of the preceding BWR/6. However, primarily due to the elimination of the external recirculation system, there is actually more room to conduct maintenance operations. To simplify maintenance and surveillance during scheduled outages, permanently installed monorails and platforms permit 360° access, and both the upper and lower drywells have separate personnel and equipment hatches. To simplify RIP and FMCRD maintenance, a rotating platform is permanently installed in the lower drywell, and semi-automated equipment was specially designed to remove and install that equipment. The wetwell area is compact and isolated from the rest of containment, thus minimizing the chance for suppression pool contamination with foreign material.

A new Reactor Building design surrounds the containment and incorporates the same functions as the BWR/6 auxiliary, fuel and diesel-generator buildings. Its volume (including containment) is about 30% less than that of the BWR/6 and requires substantially lower construction quantities. Its layout is integrated with the containment, providing 360° access with servicing areas located as close as practical to the equipment requiring regular service. Clean and contaminated zones are well defined and kept separate by limited controlled access. The fuel pool is sized to store at least ten years of spent fuel plus a full core. Therefore, the BWR/6-type fuel transfer system has been eliminated.

Controls and instrumentation were enhanced through incorporation of digital technologies with automated, self-diagnostic features. The use of multiplexing and fiber optic cable has eliminated 1.3 million feet of cabling. Within the safety systems, the adoption of a two-out-of-four trip logic and the fiber optic data links have significantly reduced the number of required nuclear boiler safety system related transmitters. In addition, a three-channel controller architecture was adopted for the primary process control systems to provide system failure tolerance and on-line repair capability.

A number of improvements were made to the Neutron Monitoring System (NMS). Fixed wide-range neutron detectors have replaced retractable source and intermediate range monitors. In addition, an automatic,

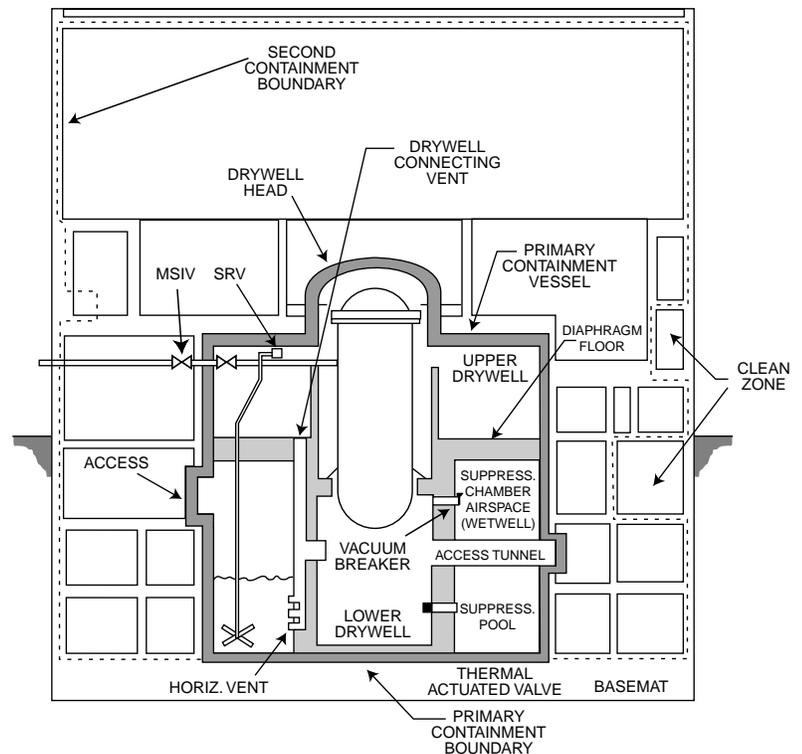


Figure 2-4. ABWR Reactor Building and Containment

period-based protection system replaced the manual range switches used during startup.

The man-machine interface was significantly improved and simplified for the ABWR using advanced technologies such as large, flat-panel displays, touch-screen CRTs and function-oriented keyboards. The number of alarm tiles was reduced by almost a factor of ten. Many operating processes and procedures are automated, with the control room operator performing a confirmatory function. Figure 2-5 illustrates the main control room.

The plant features discussed above, while simplifying the operator's burden, have an ancillary benefit of increased failure tolerance and/or reduced error rates. Studies show that less than one unplanned scram per year will be experienced with the ABWR. Increased system redundancies will also permit on-line maintenance. Thus, both forced outages and planned maintenance outages will be significantly reduced.



Figure 2-5. ABWR Main Control Room

Minimization of Radiation Exposure and Radwaste

The ABWR combines advanced facility design features and administrative procedures designed to keep the occupational radiation exposure to personnel as low as reasonably achievable (ALARA). During the design phase, layout, shielding, ventilation and monitoring instrument designs were integrated with traffic, security and access control. Operating plant results were continuously integrated during the design phase. Clean and controlled access areas are separated.

Reduction in the plant personnel radiation exposure was achieved by (1) minimizing the necessity for and amount of personnel time spent in radiation areas and (2) minimizing radiation levels in routinely occupied plant areas in the vicinity of plant equipment expected to require personnel attention.

Changes in the materials have a significant effect on the quantity of radwaste generated through radioactive corrosion products. In addition, the condensate

treatment system was improved to include both pre-filtration and deep bed demineralizers without regeneration which reduce liquid and solid radwaste input. Radwaste reduction in the ABWR can also be facilitated through the use of advanced incineration and super-compaction technologies.

Reduced Capital Cost

Design simplifications and quantities reductions as discussed above, together with an increase in plant electrical output, combine to make a significant improvement in plant capital cost. Plant economics are discussed more fully in Chapter 11.

Click navigation buttons below to go to

[Previous Chapter](#)

[Next Chapter](#)

[Table of Contents](#)