Effective Alarm Sounds Solution:

- Key features of the HCS alarm sounds include:
  - Unique three-tone combinations to differentiate between consoles
  - Consistent, unique tone speeds to differentiate alarm priorities
  - Fundamental frequencies chosen from humans' most sensitive hearing region
  - Multiple harmonic frequencies to address both masking from environmental noise and hearing deficiencies in the operator workforce
  - Onset and offset envelopes to eliminate abruptness and the associated 'startle effect'
- A unique set of WAV files for each console
- Used operator input to design the alarm notes
- Usability results showed that all consoles had a positive, overall ratings and positive comments from operators

Bottom Line

Alarm Sounds for Multi-Console Control Rooms™ communicate more information, take advantage of human strengths, and are well received by operators.

Alarm Sounds for Multi-Console Control Rooms™

The HCS Alarm Sounds for Multi-Console Control Rooms™ feature a suite of console-specific alarm sounds that simultaneously differentiate between console locations as well as alarm priority. Moreover, the HCS Alarm Sounds for Multi-Console Control Rooms™ have been designed using effective human factors principles with respect to human audition and hearing. Moreover, the HCS Alarm Sounds for Multi-Console Control Rooms™ have been operator-evaluated for both the initial design parameters as well as the in-use effectiveness. The HCS Alarm Sounds for Multi-Console Control Rooms™ design includes:

- Unique three-tone combinations to differentiate between consoles
- Consistent, unique tone speeds for each alarm priority level, across all console-specific alarm sounds, to differentiate alarm priorities
- A fundamental frequency for each alarm sound chosen from humans' most sensitive hearing region
- Each alarm sound comprised of multiple harmonic frequencies, to address both potential masking from environmental noise as well as potential hearing deficiencies in the operator workforce
- Specified onset and offset envelopes to eliminate abruptness and the associated 'startle effect'

HCS partners have been key contributors in research studies conducted within the ASM® Consortium to understand challenges associated with current industry practices and to develop new concepts to improve operators' ability to prevent and respond to abnormal situations. In addition, HCS's recent work with process industry clients has advanced the state of the art in operator interface design techniques, including the design of audible alarm annunciation. These innovations are embodied in the HCS Alarm Sounds for Multi-Console Control Rooms™.

HCS works collaboratively with clients to assign the Alarm Sounds for Multi-Console Control Rooms™ WAV files to each console position, based on console layout within their control rooms, to maximize the differentiation between alarms from each console. HCS continues to extend the distinctiveness of their alarm sounds by applying music theory and instrument effects to better support console differentiation.

Can Human-Centered Alarm Sounds Make a Difference?

In the early 1980s, the UK's Civil Aviation Authority (CAA) developed a protocol for designing auditory alarms for the avionic systems that were being added to cockpits. Roy Patterson's idea at the CAA was to design alarm sounds that indicated the alarm's urgency while simultaneously indicating which system generated the alarm without creating 'startle'

reactions or interfering with pilots' ability to communicate and think. HCS has adapted Patterson's protocol to create Alarm Sounds for Multi-Console Control Rooms™.

The figure to the right shows a conceptual drawing of how these alarm sounds have been designed. For a single console, each color can be thought of as a unique sounding note. Each console has a unique note pattern. That pattern is the same for that console for all three alarm priority levels. However, this 'melody' is repeated slowly once for low-priority alarms, repeated twice slightly faster for high-priority alarms, and repeated three times faster still for emergency-priority alarms.
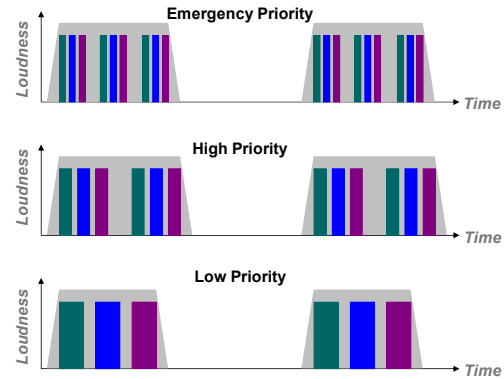
Professional operators played a vital role in the development of the Alarm Sounds for Multi-Console Control Rooms™. HCS worked with console operators to determine the most appropriate note and pause lengths to create the 'melodies' for the low-, high-, and emergency-priorities. In addition, HCS drew upon musical composition theory to combine the individual notes into melodies that are pleasing to the ear and do not create additional stress themselves.

Conceptual Drawing of the HCS Alarm Sounds for Multi-Console Control Rooms ™

Operator Usability Findings

HCS has evaluated the usability and usefulness of the HCS Alarm Sounds for Multi-Console Control Rooms™ across four shifts of four console positions in the same control room. The table to the right summarizes the operators' feedback ratings. Overall, the ratings by indicated positive acceptability on most dimensions for all consoles. All consoles had a positive, overall acceptability rating and most operators provided very positive comments about the alarm sounds.

Operators reported some inability to discriminate between consoles, but this mostly occurred when they were at team table in center of room or when similar console alarm sounds were coming from across the room. HCS re-assigned alarm sounds to maximize disparity of patterns between consoles and operator reported improved discrimination.

Operator Acceptability Ratings

Performance Impact Characteristics	Acceptability Rating (+3 to -3)
Recognize my sound from others	0
Distinguish alarm priority level	+1.8
Interference with communications	+2.1
Difficulty hearing my alarm sound	+2.5
Annoyance of my alarm sound	+1.9
Distraction from other consoles	+1.1
Contribution to my workload	+2.4
Overall Rating	**+1.8**

About HCS

Human Centered Solutions (HCS) is a multi-disciplinary group of psychologists and engineers who apply human-centered design to enhance the performance of people in and around the control rooms. In addition to auditory alarm sounds as part of the overall Advanced Operator Interface™, HCS provides expertise in operator staffing, alarm management, console workstation design, control room and building design, procedure system design, training system design, and work process design.

HCS is an active member of the ASM® Consortium and is currently involved in their research program.