

## Appendix D: PPE Examination Report

**Examination of Selected PPE Worn by Lieutenant Nathan Flynn  
During July 23, 2018 Structure Fire at  
7005 Woodscape Drive, Clarksville, MD**

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**Examination of Selected PPE Worn by Lieutenant Nathan Flynn  
During July 23, 2018 Structure Fire at  
7005 Woodscape Drive, Clarksville, MD**

**October 31, 2018**

**Summary**

This report describes my examination of selected personal protective equipment items worn by Lieutenant Nathan Flynn who died as a result of injuries sustained in a structure fire at 7005 Woodscape Drive, Clarksville, MD on July 23, 2018. A review was conducted for the condition of the PPE items that were provided for examination and other information provided by the Howard County Department of Fire and Rescue Services.

In general, Lieutenant Flynn was part of an entry team into the burning structure and fell through the entry level floor into a large basement crawlspace area where he remained for approximately 22 minutes before he was extricated by the department Rapid Intervention Team. No other specific details are provided for the incident in this report. Instead, a detailed narrative is available from the Howard County Department of Fire and Rescue Services.

For the purposes of this examination, the protective helmet, protective hood, protective coat, protective pants, left protective glove, and protective footwear were provided for examination. The right protective glove was not recovered from the fireground and the SCBA was subjected to a separate evaluation by the National Institute for Occupational Safety and Health. The examined items were subjected to a rigorous visual inspection on all surfaces of the clothing items to assess how the specific areas of damage might be related to the protective qualities of the respective items. The protective garments (coat and pants) were further examined for their compliance with the purchase specifications for the Howard County Department of Fire and Rescue Services. The elements most affected included the protective helmet and protective coat. Significant thermal degradation was observed for the protective helmet while there was significant heat penetration on parts of the protective coat primarily in the left back shoulder and lower left back side. Thermal damage was noted for other clothing elements including the back of the protective pants, left glove, and both boots. The helmet was significantly affected by the fire exposure.

No specific defects or issues were found with the quality of the examined clothing items that could be considered as contributing to the adverse injuries sustained by Lieutenant Flynn. All clothing items were found to meet the relevant edition of NFPA 1971 at the time of their manufacture with the exception of the hood, for which the product label was missing. The coat and pants had all of the requisite features and materials as indicated on the purchase specification. Nevertheless, these items were not originally issued to Lieutenant Flynn. Both the protective helmet and the protective footwear had dates of manufacturing that are more than 10 years relative to the fire incident. These items should have been retired from service but would have not affected the protection levels afforded to Lieutenant Flynn. It further appears that the protective coat collar was not worn in its deployed position and the hood was altered to connect to the coat collar; however, these factors also did not likely exacerbate any exposure conditions to Lieutenant Flynn.

### **Objective**

I was asked by the Howard County Department of Fire and Rescue Services to determine if there were any defects or other factors related to the personal protective equipment items worn by Lieutenant Nathan Flynn that may have contributed to his injuries sustained while engaged in a structural fire that ultimately led to his death.

### **Overview of the Incident**

A complete description of the incident is provided in a separate report being prepared by the Howard County Department of Fire and Rescue Services. For the purposes of this report, Lieutenant Flynn was part of an entry team where upon after advancing into the structure fell through the entry level floor into a large basement crawlspace area. Approximately 22 minutes elapsed from the time that Lieutenant Flynn fell into the basement until the time he was extricated by the Rapid Intervention Team. The residential structure at 7005 Woodscape Drive, Clarksville, MD on July 23, 2018 was described as a relatively large, custom-built, multi-floored mansion. A photograph of the fire operations at this location pulled from local new media appears in Figure 1.



**Figure 1 – Photograph of Structure During Fire Operations**

### **Specific Description of Firefighter Injuries or Cause of Death**

At the time this report was prepared, no specific information was provided regarding any burn areas for the subject firefighter or the cause of his death. This information is being separately provided by the Howard County Department of Fire and Rescue Services.

### **Methodology Used in Evaluation**

The primary approach in evaluating the provided items of personal protective equipment (PPE) was through a detailed inspection. Clothing and equipment were specifically evaluated for:

- Compliance with the relevant editions of NFPA 1971 standards at the time the item was indicated as being manufactured
- Conformity of the product design to the relevant design requirements of NFPA 1971
- Adherence to the Howard County Department of Fire and Rescue Services specifications (protective garments only)
- The general condition of the clothing in terms of its levels of soiling and wear
- Specific areas of physical damage and contamination
- The types, location, and severity of the thermal damage of the clothing
- Evidence of how the clothing item was worn and exposed
- Indications of prior care and maintenance

Knowledge of the general thermal environment conditions faced by the respective firefighters is used to assist in the characterization of the thermal damage sustained by the clothing. Particular attention is generally given to examining areas of the clothing or equipment that covered or was adjacent to known areas of personal injury. For this incident, specific locations of burn injury were not provided. Patterns of soiling and damage may be indicative of whether the clothing or equipment item was properly worn.

Observations for the types of damage found on different parts of the clothing and equipment items can provide clues as to the severity of the thermal exposures encountered by the respective firefighter. Many materials provide thermal signatures, i.e., telltale signs of specific damage that can be linked to certain exposure temperature or energies. For example, some dyed outer shell materials are known to release the dye through a process called dye sublimation (evaporation of the dye chemicals) at known temperatures. In addition, particular components of the clothing, such as trim, will tend to degrade at lower temperatures than the base materials used in the clothing's construction.

Where possible, assessments are made on interior layers and surfaces to determine the level of heat penetration that can be used to assess the propensity of heat transfer that can lead to burn injury. The relative susceptibility of each clothing or equipment layer and component is taken into account for judging the overall exposure levels and determining how the clothing or equipment item performed in the exposure environment.

## The Fireground Environment and Its Effects on the Protective Clothing

One approach to analyze the burn injuries to the respective firefighters and the damage to their protective clothing is to examine industry information that shows the range of fireground conditions that can be experienced and relate these conditions to the types of damage that can occur to clothing and equipment. The relationship between increasing thermal radiation (expressed in  $\text{cal}/\text{cm}^2\text{s}$ ) and the resulting rise in air temperature (expressed in degrees Celsius and degrees Fahrenheit) is presented in the figure below. Possible structural fire fighting situations are illustrated in this figure:<sup>1,2</sup>

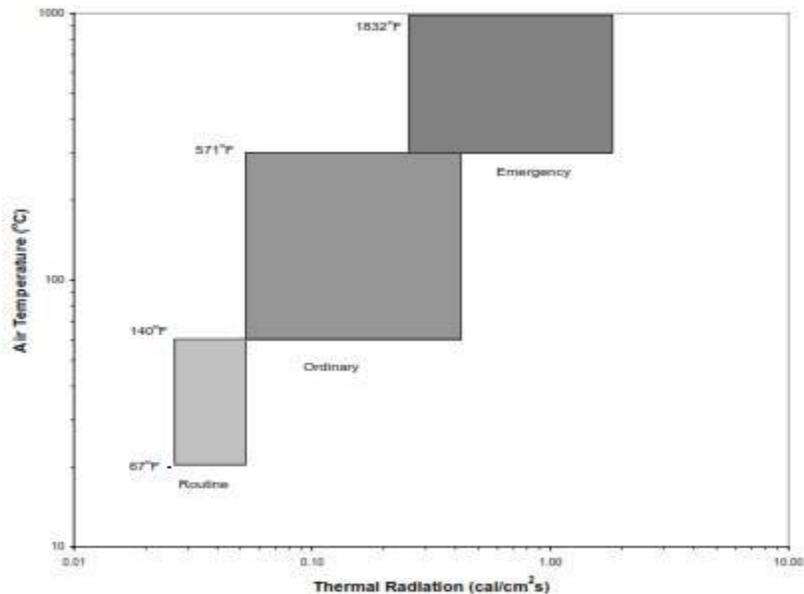


Figure 2 – Classification of Fireground Exposures

- The **Routine** region describes conditions where one or two objects, such as a bed or waste basket, are burning in a room. The thermal radiation and the air temperatures are virtually the same as those encountered on a hot summer day. As shown in Figure 17, **Routine** conditions are accompanied by a thermal radiation range of 0.025 to 0.05  $\text{cal}/\text{cm}^2\text{s}$  and by air temperatures ranging from 68 to 140°F. Protective clothing for firefighters typically provides protection for tens of minutes under these conditions, but excessively long exposure times may still create a burn injury situation.

<sup>1</sup>N. J. Abbott and S. Schulman, "Protection from Fire: Nonflammable Fabrics and Coatings, *Journal of Coated Fabrics*, Vol. 6, July 1976, pp. 48-64.

<sup>2</sup>H. P. Utech, "High Temperatures vs. Fire Equipment," *International Fire Chief*, Vol. 39, 1973, pp. 26-27.

- The **Ordinary** region describes temperatures encountered in fighting a more serious fire or being next to a "flash-over" room. **Ordinary** conditions are defined by a thermal range of 0.05 to 0.6 cal/cm<sup>2</sup>s, representing an air temperature range of 140 to 571°F. Under these conditions, protective clothing may allow sufficient time to extinguish the fire or to fight the fire until the nominal air supply is exhausted (usually at periods limited to several to tens of minutes).
- The **Emergency** region describes conditions in a severe and unusual exposure, such as those caused inside a "flash-over" room or next to a flame front. In **Emergency** conditions, the thermal load exceeds 0.6 cal/cm<sup>2</sup>s and temperatures exceed 571°F. In such conditions, the function of firefighters' clothing and equipment is simply to provide protection during the short time needed for an escape without serious injury.

The specific fireground conditions have not been described for this incident. However, the fire was described as a multi-alarm requiring several hours to bring under control. There was also an extended period of time that occurred, estimated to be approximately 22 minutes, for the department Rapid Intervention Team to enter the structure and to extricate Lieutenant Flynn. This information suggests that a wide range of fireground conditions that likely existed at high ordinary to low emergency conditions for at least part of the time for which Lieutenant Flynn was in the basement.

#### **Identification and Examination of PPE Items Worn by Deceased Firefighter**

The following personal protective equipment (PPE) items worn by Lieutenant Flynn were provided for examination:

- Protective coat
- Protective trousers
- Protective helmet
- Protective hood
- Left protective glove
- Protective footwear

The right protective glove was not recovered. Further it was reported that the left protective glove was recovered inside the structure after the incident and had come off during the extrication of Lieutenant Flynn. Similarly, the left boot had come off during Lieutenant's Flynn's extrication and was recovered after the incident.

It was reported that the protective garments, including coat and pants, were issued to other firefighters by the Howard County Department of Fire and Rescue Services prior to the items being issued to Lieutenant Flynn. The protective coat was originally manufactured in 2014 for another firefighter, but did not fit the firefighter. The protective coat was reissued to Lieutenant Flynn in a new condition on 4 October 2016. Similarly, the protective pants were originally manufactured in 2014 for a different firefighter and were reissued to Lieutenant Flynn on 4 October 2016. The pants were sent for cleaning on 3 November 2015. There were no other cleaning records available for this item.

Table 1 provides an overview of the different PPE items worn by Lieutenant Flynn. This table provides identifying information on each PPE item and the general observations for the condition of each item as provided to International Personnel Protection for examination. Each item was subjected to full inspection and was extensively photographed to show its overall condition.

**Table 1 – Specific Identification and Condition of PPE Items for Lieutenant Flynn**

PPE Item	Identifying Information	Observed Conditions
Protective coat	Manufacturer: Honeywell Model: LTO1513TG Serial: 1404010275 Date of Mfr.: 5/22/2014 Size: Chest 42; Front 27; Back 33; Sleeve 33 (“Measured for Norman”) Outer shell: Omi Vantage – 7.8 oz. Moisture Barrier: Crosstech Black Type 2F – 4.7 oz Thermal Barrier: Synergy II – 7.0 oz. Certification: NFPA 1971-2013 Dear Air Panels internal liner reinforcements on shoulders and lower arms. Articulating Drag Rescue Device Hook and pile front closure with hooks and dee hardware	<ul style="list-style-type: none"> <li>• Cut open along sleeves and collar</li> <li>• Severe charring with break open on upper back left shoulder and left lower side through tail</li> <li>• Disintegration of lettering on left back; severe damage to trim bands on sleeves</li> <li>• Charring of department patch on left sleeve</li> <li>• Charring to liner at upper left back shows heat penetration through all layers</li> <li>• Examination through inspection port shows some melting of moisture barrier and seams in lower upper back area</li> <li>• DRD shows no signs of deployment</li> </ul>
Protective pants	Manufacturer: Honeywell Model: LTO1513PG Serial No. 1312006002 Date of Mfg.: 7/12/2016 Size: Waist 38; Inseam 30 (“Measured for Hand”) Outer shell: Omi Vantage – 7.8 oz. Moisture Barrier: Crosstech Black Type 2F – 4.7 oz Thermal Barrier: Synergy II – 7.0 oz. Certification: NFPA 1971-2013 Written by hand next to product label: Hand, John 3971, 05/14 Biflex heat channel knee reinforcements Hook and pile front fly with hood and dee hardware	<ul style="list-style-type: none"> <li>• Significant thermal damage on back left side in seat area at back pocket and lower back leg; lesser damage to back of right leg</li> <li>• Char marks on lower back right leg</li> <li>• Deterioration of trim band at back of lower leg; minor thermal damage to trim band at back of right leg</li> <li>• Molten residue on middle of left knee reinforcement</li> <li>• Charring on moisture barrier side of liner on upper and lower back leg; char marks appears on lower right leg</li> <li>• Examination through inspection port shows discoloration of moisture barrier film on upper and lower legs area; also charring of batting side of moisture barrier in seat area</li> </ul>

PPE Item	Identifying Information	Observed Conditions
Protective helmet	Manufacturer: Cairns Model: N6A Houston Helmet Shop Order: 101243173 Order: 2441126 Sequence Count: 60-1 Color: 33 Yellow Size: Medium Ear Flap: L955B (Nomex) Chin Strap: PC893 Eye Protection: S550 Liner: LK2 B Model Weight: 77 oz. Misc: 43884 Customer: 300827 Date of Mfg: 6/18/2007 Certification: NFPA 1971-2007 Shell/interior materials: Leather over Lexan outer dome, high temperature urethane foam and with ABS inner liner	<ul style="list-style-type: none"> <li>• Helmet has significant thermal damage and warping over entire shell and brim</li> <li>• Entire helmet is blackened with thermal degradation of exterior shell surface including underside of front/rear brims</li> <li>• No evidence of reflective markings being present</li> <li>• Deterioration of brim edges with shrinkage away from wire frames</li> <li>• Front shield warped/distorted</li> <li>• Ear covers severely soiled on exterior with moderate interior soiling</li> <li>• Distortion of end of chin strap</li> </ul>
Protective hood	Manufacturer: Unknown Model: Unknown Date of Mfg.: Unknown Lot No.: Unknown Material: 100% Nomex or Nomex blend likely Certification: Unknown	<ul style="list-style-type: none"> <li>• Heavy soiling on front of hood around face opening and majority of front bib and back area above back bib</li> <li>• Likely blood stains on front of hood bib area</li> <li>• Four holes punched in back hood bib corresponding to coat collar snap locations</li> </ul>
Protective glove (left only)	Manufacturer: Shanghai Hygloves Company Model No. 7877 Date of Mfg.: 6/4/2017 Size: Large Shell: Goatskin, Kevlar, Cowhide Moisture Barrier: Polyurethane Lining: Kevlar knit Gauntlet style Certification: NFPA 1971-2013	<ul style="list-style-type: none"> <li>• Heavy soiling over entire exterior surface of glove including splotchy white material</li> <li>• Likely shrinkage for glove, though new glove unavailable for comparison</li> <li>• Moderate to heavy soiling inside glove on liner including fibrous debris</li> <li>• Some liner tearing inside glove</li> </ul>

PPE Item	Identifying Information	Observed Conditions
Protective footwear	Manufacturer: Honeywell Model: 3009 Size 9.5 D Style: 4N30002C Serial No. WP310274034 (right) Left boot serial number unreadable Leather outer Crosstech Cambrelle bootie package with Kevlar exterior reinforcement under leather Certification: NFPA 1971-2000	<ul style="list-style-type: none"> <li>• Significant difference in appearance between left and right boots</li> <li>• Left boot shows light soiling on surface of leather, burnt away leather on front toe and separation of outer sole from midsole at heel</li> <li>• Right boot was recovered from fireground after incident and exhibits shrinkage and distortion of upper, white blotchy soiling over most of exterior and debris inside boot</li> </ul>

Photographs for each item are presented in Appendix A of this report and are referred to in the following narrative describing the clothing and equipment's condition starting with the protective helmet.

**Protective Helmet.** The protective helmet worn by the Lieutenant Flynn showed extensive thermal damage. The helmet was of a leather construction and the top, front, rear, left, and right views (Figures A-1 through A-5) show that the entire surface was blackened and distorted with significant degradation and shrinkage of the leather, particularly along the front and left back brim areas. For example, Figure A-2 displays a darkened and distorted shield along with separation of the front brim from the underlying wire rim. Damage to the back brim of the helmet is shown in Figures A-3 and A-4. Figure A-6 provides a view of the underlying brim showing equal levels of damage and distortion of leather surfaces. This view also shows the severe soiling and charring of the extended helmet ear covers. The interior side of the ear covers shows the knit lining material is less soiled and includes some molten residue towards the front as seen in Figure A-7. A close-up of the charring on the back brim is provided in Figure A-8, which also depicts the inability to read the warning label. Product label information seen through the helmet suspension is shown in Figure A-9. It is noted that the helmet was manufactured in June 2007 (over 10 years old as of the accident date). The certification label provided in Figure A-10 shows that the helmet was certified to the 2007 edition of NFPA 1971.

**Protective Hood.** Photographs for the front and back of the protective hood are provided in Figures A-11 and A-12. However, there was no product label present in the hood and no way to identify its manufacturer, model number or style name, date of manufacture, or certification. The hood appears to be a 2-ply 100% Nomex or Nomex blend knit. The pictures of the hood show moderate to heavy soiling with the heaviest soiling around the face opening and on the front of the bib. The latter suggests that the front hood bib was either worn out, or pulled out sometime during the time that Lieutenant Flynn was on the fireground. There are also some reddish brown spots on the left side of the hood bib, which could be dried blood. The soiling pattern on the back of the hood (Figure A-12) extended from below the helmet to a series of four holes in a circular arc on the back of the hood. Soiling was heaviest towards the left side. Information from the department conveyed that the holes were likely the result of intentional modification of the hood

to allow the hood to be snapped into the coat liner at the back of the hood. It was explained that this practice was used by some firefighters in the department to help secure the back of the hood inside the coat. Figure A-3 shows the protective hood inverted and includes a view of the hood opening area showing some moderate soiling and light charring that penetrated the left side (appearing on the right side in the photograph). Figure A-14 is a photograph of the lower left side of the hood bib interior, which shows “Flynn 3633” below a couple of apparent dried blood spots, indicating that this item had been issued to Lieutenant Flynn.

**Protective Coat Shell.** Figures A-15 and A-16 provide front and back views of exterior side for the Lieutenant Flynn’s protective coat outer shell. The coat outer shell was actually cut along the length of the sleeves and shoulder. Nevertheless, the coat was positioned together for the photographs as if the coat was still intact. The greatest damage of the coat appears on the left side and particularly at the upper left back shoulder and lower left back side. Both sleeves are heavily soiled, more than much of the other parts of the outer shell. Figures A-17 and A-18 further show damage to the offset trim bands near the sleeve ends, primarily on the back of the sleeves. Figure A-19 provides a close-up of the deteriorated department patch on the left upper sleeve. The extensive charring and break open of the outer shell at the upper left back shoulder area are shown in Figure A-20. This picture also shows missing lettering on the left back of the coat that likely burned away. Similar severe damage is shown on the lower left side of coat next to the left bottom cargo pocket in Figure A-21. The photograph in Figure A-22 shows the pull tab for the coat drag rescue device (DRD) in place, indicating that it was not deployed during the extrication of Lieutenant Flynn from the fireground.

Figure A-23 shows the entire interior view of the protective coat outer shell. The ability for observing charring is best illustrated with this photograph since charring will usually penetrate through the entire outer shell layer whereas soiling generally does not. This charring is most evident in the upper left back and shoulder as well as the lower left side on the back coat tail area. A close-up of this damage is shown in Figures A-24 and A-25. The interior side of the collar is shown in Figure A-26, which shows heavy soiling and suggests that the collar was not in the required raised orientation during the fire event. The coat outer shell product identification label appears on the right closure facing material in Figure A-27.

**Protective Coat Liner.** Photographs of the moisture barrier and thermal barrier sides of the protective coat lining are provided in Figures A-28 and A-29. These photographs show the extreme heat penetration at the left upper shoulder and back areas of the protective coat. Close-up views of the damaged areas at the back on the moisture barrier side (Figure A-30) and corresponding areas on the thermal barrier layer facing the Lieutenant Flynn (A-31) indicate heat penetration through all 3 principal layers of the protective coat. Figure A-31 further shows a close-up of melting for the moisture barrier film and seam tapes in the same upper back shoulder area as found inside the liner. Additional insulation designed into the coat in form of sewn on strips (referred to as “dead air panels” by Honeywell) is present at the upper back along both shoulders and over the upper and lower arms as shown in Figures A-33 and A-34. An elbow insulation layer is also present. Figure A-32 shows some light charring near the shoulder area on the left side of the garment at the interior batting. Product labels appear in Figure A-35 with a close-up of the product compliance label in Figure A-36 (NFPA 1971-2013). The product label indicates that the coat was measured for “Norman.”

**Protective Pants Shell.** The front and back of the exterior side of outer shell for Lieutenant Flynn's protective pants are shown in Figures A-37 and A-38. The front of the pants shows moderate soiling along the front of the pants with the heaviest soiling at the left knee area where there is a melted resin-like deposit on the right side of the knee reinforcement; there is also a stain at the bottom of the right lower leg in the cuff area (see Figure A-39). The back of the pants show thermal damage with charring along the majority of the left leg particularly on the back pants pocket, upper leg cargo pocket, and lower pant leg. Damage to the back left pants pocket is seen in Figure A-40 while the disintegrated lower trim band on the back of the left leg is shown in Figure A-41. In comparison, the back lower right leg is shown in Figure A-42, which shows melted resin on part of the trim band and char marks to right of the lower back leg. The interior front and back sides for the pants outer shell are pictured in Figure A-43 and A-44. In these photographs, there is some penetration of charring as seen in left side of the pants (opposite of what is seen in the picture) primarily on the lower leg, though there is no internal charring in the back pocket area because of the multiple layers of fabric in the pants design element. The burn mark above the trim band on the right leg can clearly be seen on Figure A-45. The pants outer shell product identification label appears on the right closure facing material in Figure A-46.

**Protective Pants Liner.** Interior views for the front and back of the lining moisture barrier side are shown in Figures A-47 and A-48. The front view shows only moderate soiling with some light charring at the bottom of the left leg near the hem. However, the back shows charring in several areas including around the seat pockets, upper left inner leg and lower back leg. The char marks noted on the lower right leg coincide with similar marks on the moisture barrier in Figure A-49 and a closer view of the char damage is seen in Figure A-50, including the area where the trim disintegrated. Relatively little to no thermal damage is shown on the innermost layer of the lining as shown in Figures A-51 and A-52. Instead, there is moderate to heavy soiling, particularly in the area of the lower legs. There is mild discoloration and some soiling, particularly near lower left leg. The full protective pants product label and warnings are shown in Figure A-53, indicating compliance with the 2013 edition of NFPA 1971. Information written above the label in indelible ink include "Hand, John 3971 05/14. A close-up of the compliance label indicates that the pants were measured for "Hand."

An inspection of the liner interior was performed by inverting the lining through the inspection opening near the fly section of the protective pants pictured in Figure A-55. In this fashion, the moisture barrier film (dark gray) and thermal barrier batting (light yellow) layers of the liner are attached as seen in Figure A-56. The film side of the pants lining is presented in Figure A-57 while the batting or insulation side is shown in Figure A-58. Figures A-59 shows discoloration of the moisture barrier film along the left leg indicating high heat exposure on either side of the knee reinforcement. Figure A-60 shows corresponding charring in the same areas on the thermal barrier batting layer. Figure A-61 provides an interior view of the extra reinforcement material placed at the knee area inside the liner. Figure A-62 show charring in the seat area of the pants primarily between the back pockets.

**Protective Gloves.** Only one of the protective gloves worn by Lieutenant Flynn was recovered. It was reported that neither glove was on Lieutenant Flynn's hands when he was removed from the structure; however, was further undetermined at what point during the Mayday or rescue operation that each of the gloves came off his hands. The left glove was found after the incident,

several hours after Lieutenant Flynn had been removed from the structure. The back of the glove is shown in Figure A-61 while the palm side is shown in Figure A-62. The glove is heavily soiled with a white splotchy soiling over both back and palm sides, which was also characteristic of the contamination on some portions of the protective coat and pants. This soiling or contamination extends into the interior of the glove as seen in Figure A-63. This photograph further shows some wear on the glove interior. Labels provided for the glove show its compliance to the 2013 edition of NFPA 1971 (Figure A-64), the care instructions (Figure A-65), and the manufacturing date (Figure A-66).

**Protective Footwear.** Photographs of the exterior left and right sides of Lieutenant Flynn's protective footwear are provided in Figures A-67 and A-68. These photographs show a stark contrast in the condition of the footwear. The left protective boot came off of Lieutenant Flynn during his extrication and was not recovered until after the incident. Consequently, the left protective boot shows much more extensive soiling and fireground debris as compared to the right boot. It is further evident in the photographs including the close-up provided in Figure A-69 that there was distortion (and shrinkage) of the left boot as the result of extended high heat exposure. In comparison, the right boot has only light soiling, but it also shows the effects of high heat exposure. Figure A-70 shows degradation and missing piece of the leather covering the front of the toe cap. Figure A-71 show separation of the outer sole from the mid sole of the right protective boot in the heel area though the welt stitching is still intact. The product label inside the boot is seen in Figure A-72 which shows the product information, the size, and serial number. The compliance statement indicates certification to the 2000 edition of the NFPA 1971, which is well beyond the maximum service life of protective elements specified by NFPA 1951. For the left boot (label shown in Figure A-72, the serial number and bar code were completely faded in contrast to the right boot label provided in Figure A-73).

## **Findings and Conclusions**

**Characterization of the Exposure Environment.** Certain portions of the clothing reached temperatures well above 500°F with some of these areas being at high temperatures for extended periods of time. Complete degradation of trim material on the garments and helmet indicated temperatures in excess of 600 to 700°F. Charring and break open of the outer shell material is caused by similar or slightly higher temperatures. Heat penetration was further noted on certain areas (upper back) of the garment from the shell to underlying layers, including the seam tape of the moisture barrier and the innermost lining of the thermal barrier, which would have been adjacent to Lieutenant Flynn's station/work uniform. Heat penetration of this type is equivalent to heat exposure energies to the garments of 40 to 50 cal/cm<sup>2</sup>. In perspective, this level of heat energy is above the minimum level of insulation required by thermal protective performance testing (35 cal/cm<sup>2</sup>), which is used to simulate a flash fire condition, but undoubtedly involved a much lower radiant, convective, or conductive heat exposure rate for a considerably longer period of time. It is important to point out that these areas of high heat penetration were localized to only portions of the clothing and thus the heat energy levels experienced by Lieutenant Flynn were not uniform and thus varied significantly over his personal protective equipment. Nevertheless, it is also important to realize that the exposure conditions while not of the emergency or flashover conditions described above, were well in excess of the conditions for which the clothing and equipment items could provide adequate protection.

**Damage Patterns on Clothing.** An examination of the protective clothing showed uneven levels of thermal damage, which is common for protective clothing exposed in structural fires. Information provided by the Howard County Department of Fire and Rescue Services indicated that Lieutenant Flynn was found face down on his left when extricated by the Rapid Intervention Team. The greatest damage to Lieutenant Flynn's protective garments were on the left side, but towards the back. There is also more damage to left side of the hood and helmet, but no comparison can be made for either the gloves or footwear since only one glove was recovered and one boot remained on the fireground following extrication. The damage predominately on the left side and the fact that this damage is not uniform along the left side could be explained by the likelihood that sometime during his time in the basement crawl space, Lieutenant Flynn could have been in contact with burning debris or embers on his left side. However, the RIT advised that he was not trapped or covered with debris.

**Firefighter Injuries Relative to Clothing Damage.** Insufficient information was made available to provide any comparison between damaged areas of the clothing and skin (burn) damage to Lieutenant Flynn.

**Clothing and Equipment Damage as Related to Item Protective Performance.** Some items of protective clothing and equipment were more damaged than others. As already explained, certain items had significantly varying levels of damage due to the orientation of Lieutenant Flynn in the structure and the dynamic conditions of the fire exposure. Yet, some differences in performance are noteworthy. In particular, while leather helmet shell materials are viable for the majority of fireground operations, leather materials will deteriorate at lower temperatures than many synthetic high temperature polymeric materials. Extended exposure to relatively high temperatures causes distortion and shrinkage of leather. This was also evident on the two boots where right boot came out of the fireground with Lieutenant Flynn and the left boot was recovered later.

**Protective Garment Conformance to Manufacturing Specifications.** Both the protective coat and protective pants were compared to the manufacturing specifications. It is noted that these garments were made based on measurements of different firefighters and not Lieutenant Flynn. Therefore, no assessment can be made with regard to the relative fit of the two protective garments for Lieutenant Flynn, particularly since his dimensions were not provided. Relative to the specific identified materials, including reinforcement layers, and other features indicated in the purchase specifications, all items that could be identified were present and consistent with the indicated list of specification items.

**Protective Clothing Service Life.** All of the examined clothing and equipment were compliant to a relevant edition of the NFPA 1971 standard when provided to Lieutenant Flynn. Two items were beyond the recommended 10-year service life. These included the protective helmet. According to NFPA 1851-2014 (*Standard on the Selection, Care, and Maintenance of Protective Ensembles for Structural Fire Fighting and Proximity Fire Fighting*), structural firefighting protective elements that are more than 10 years past the manufacturing date should be retired. This was the case for the protective helmet that was worn by Lieutenant Flynn by approximately one month. The protective footwear was much older. While no manufacturing date could be discerned off from the footwear, the product label indicated compliance to the 2000 edition of

NFPA 1971, meaning that the footwear was more than 10 years old since the next edition of NFPA 1971 became effective on August 17, 2006 with a grace period for allowing certifications to the older edition through March 1, 2007. It is further uncertain if the condition of both the protective helmet and the footwear could have shown signs or damage prior to their use in the July 23, 2018 fire. For example, the warning labels inside the footwear were completely worn away and the serial number of one of the boots was no longer visible. The separation of the outer sole from the midsole of the right boot (which came out with Lieutenant Flynn) could simply be due to the extended service life of this item. The same may be true of the missing outer leather on the right boot at the toe area, which was not observed for the left toe of the boot that remained on the fireground. Similarly, it is possible that some wear and tear, including thermal damage, could have been present on the protective helmet worn by Lieutenant Flynn. There is no way to fully discriminate if some damage could have been present prior to the fire incident.

Information related to cleaning was only provided on the protective garments. According to this information, only the protective pants had been subjected to an advanced cleaning. NFPA 1851-2014 specifies that clothing items should be subject to at least one advanced cleaning each year or after any fireground soiling. The indicated cleaning for the pants was approximately one and a half years prior to the fire incident. No cleaning was indicated for the protective coat since it was issued to Lieutenant Flynn.

**Observations Related to Clothing Use.** Two apparent discrepancies were noted in the wearing of the protective clothing items:

1. Holes were made in the back of the hood to allow its attachment to the back of the garment collar area between the coat shell and liner (secured by the liner snaps). While this practice may act to retain the back of the hood in place and to prevent the hood from accidentally pulling out from under coat, it is not a recommended practice for the use of structural firefighting protective ensembles and is an unauthorized modification of both the hood and the protective coat. Further, it is quite possible that fixing the position of the back hood bib could lead to front bib more easily coming out of the front of the coat. It is possible that the extensive levels of soiling appearing on the front bib may have occurred because the front bib either came out on the fireground or was never tucked in initially.
2. The patterns of soiling on the interior side of the collar suggest that the collar was not in a raised position. It is important for the collar to be raised since this wearing position helps to provide further thermal insulation to the firefighter's neck, which are not protected by the ear covers, which should also be fully extended downward. The protective hood by itself does not offer the same insulation as the other elements of clothing.

While these discrepancies are pointed out and are not contributory to any specific hazard or failure of the protective ensemble, it remains good practice to ensure that all clothing is fully and properly donned during any structural firefighting event.

**Overall Assessment of PPE.** There was no evidence of any design defect or specific item manufacturing defect in any of the PPE items that were examined. The fireground conditions, as indicated by the levels of damage observed on the clothing items and by the known time of

overall exposure faced by Lieutenant Flynn, exceeded the capacity of the protective clothing and equipment to provide full protection. I could not find any specific issue with any of the examined clothing and equipment items in terms of their selection, fabrication, manner of wearing, or maintenance that would have exacerbated the specific hazards faced by Lieutenant Flynn under the circumstances of his exposure.

### **Recommendations**

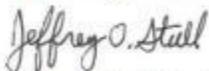
As the result of this investigation, I recommend that the Howard County Department of Fire and Rescue Services consider the following:

1. Instructions on the need and specific procedures for wearing of all personal protective clothing and equipment should be provided to each member. It is important to emphasize that all components must be deployed, and that all elements of the ensemble should be properly closed. If members indicate problems with any interface that leaves the interface area potentially exposed, corrections to the ensemble or wearing practices should be implemented for that individual. The department should specifically instruct its members on the correct wearing of protective coat collars and helmet ear covers for structural firefighting.
2. The department should discourage putting holes in the hood for their retention in the protective coat collar. These practices are not condoned by the respective manufacturers and may lead to their ineffective use with firefighter head movements. The department should also instruct firefighters on the proper wearing of hoods by indicating that the bibs should be fully tucked in before engaging in firefighting.
3. The department should employ a means for assessing the fit of clothing that is not made for a specific firefighter. This means of assessing fit should include matching the dimensions of the firefighter with the manufactured dimensions of the clothing with the advice of the clothing manufacturer and by having the firefighter wear the clothing in a series of exercises to assess freedom of movement and fit. For example, having a firefighter reach above their head and bend over are ways to assess the interface between the coat and pants. Having the firefighter also squat and reach overhead can ascertain any restriction in movement.
4. The department should review all PPE in place for its service life. Any PPE that is older than 10 years from the date of manufacturer should be removed in accordance with NFPA 1851-2014. While not all of the fire service agrees with this requirement, it has been put in place because it is extremely difficult to ascertain the continuing performance of protective clothing and equipment and secondly for the reason that NFPA standards are usually revised every 5 years and 10 years represents two cycles of revisions where significant changes in product materials, construction, and requirements can take place. If an item of protective clothing does not have a product label on which the date of manufacture can be determined, the item should be replaced or a replacement label obtained, if allowed by the manufacturer.

5. The department should institute a regular program of advanced cleaning as part of a PPE care and maintenance program. The department should confirm that it has records keeping practices in place that conform to NFPA 1851-2014.
6. For the clothing directly examined as part of the investigation, these items of clothing and equipment should be retained by the department because of its involvement in a situation where injuries were sustained. I recommend that the department retain the clothing and equipment for a period of at least 2 years with an appropriate chain of custody. The clothing should be condemned and destroyed after that period has elapsed.

Please contact me if you have any specific questions on this report.

Respectfully submitted,



Jeffrey O. Stull, President  
International Personnel Protection, Inc.  
Austin, Texas

**Appendix A**

**PHOTOGRAPHS OF EXAMINED  
PROTECTIVE CLOTHING ITEMS FOR  
LIEUTENANT NATHAN FLYNN**

A-1



**Figure A-1. Top of Lieutenant Flynn's Protective Helmet**



**Figure A-2. Front of Lieutenant Flynn's Protective Helmet**

A-2



**Figure A-3. Rear of Lieutenant Flynn's Protective Helmet**



**Figure A-4. Left Side of Lieutenant Flynn's Protective Helmet**

A-3



**Figure A-5. Right Side of Lieutenant Flynn's Protective Helmet**



**Figure A-6. Interior View of Lieutenant Flynn's Protective Helmet**

A-4



**Figure A-7. Interior of Ear Covers for Lieutenant Flynn's Protective Helmet**



**Figure A-8. Close-Up of Charring on Warning Label and Underside of Back Brim for Lieutenant Flynn's Protective Helmet**

A-5



Figure A-9. Product Label inside Lieutenant Flynn's Protective Helmet



Figure A-10. Certification Label inside Lieutenant Flynn's Protective Helmet



**Figure A-11. Front View of Lieutenant Flynn's Protective Hood**



**Figure A-12. Back View of Lieutenant Flynn's Protective Hood**

A-7



**Figure A-13. Close-Up of Front Interior of Lieutenant Flynn's Protective Hood**



**Figure A-14. Name on Inside Front Bib of Lieutenant Flynn's Protective Hood**

A-8



**Figure A-15. Front of Lieutenant Flynn's Protective Coat (Exterior Side)**



**Figure A-16. Back of Lieutenant Flynn's Coat (Exterior Side)**

A-9



**Figure A-17. Close-Up of Lower Left Sleeve of Lieutenant Flynn's Protective Coat**



**Figure A-18. Close-Up of Lower Right Sleeve of Lieutenant Flynn's Protective Coat**

A-10



**Figure A-19. Close-Up of Patch on Right Sleeve of Lieutenant Flynn's Protective Coat**



**Figure A-20. Close-Up of Thermal Damage to Left Back Shoulder Area of Lieutenant Flynn's Protective Coat**

A-11



**Figure A-21. Close-Up of Lower Back Left Side of Lieutenant Flynn's Protective Coat**



**Figure A-22. Close-Up of Soling on Pull Tab on Back of Lieutenant Flynn's Protective Coat**

A-12



**Figure A-23. Shell Interior of Lieutenant Flynn's Protective Coat**



**Figure A-24. Charred Area at Left Shoulder on Shell Interior of Lieutenant Flynn's Protective Coat**

A-13



**Figure A-25. Charred Area at Lower Left Side on Shell Interior of Lieutenant Flynn's Protective Coat**



**Figure A-26. Close-Up of Collar Interior on Outer Shell Lieutenant Flynn's Protective Coat**

A-14



**Figure A-27. Product Label on Left Front Facing on Shell Interior of Lieutenant Flynn's Protective Coat**



**Figure A-28. Moisture Barrier Side of Lieutenant Flynn's Protective Coat Liner**



**Figure A-29. Thermal Barrier Side of Lieutenant Flynn's Protective Coat Liner**



**Figure A-30. Close-Up of Charring at Shoulder Upper Back of Lieutenant Flynn's Protective Coat Liner (Moisture Barrier Side)**

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**Figure A-31. Close-Up of Charring at Shoulder Upper Back of Lieutenant Flynn's Protective Coat Liner (Thermal Barrier Side)**



**Figure A-32. Close-Up of Moisture Barrier Seams near Shoulder Areas Inside Lieutenant Flynn's Protective Coat Liner**

A-17



**Figure A-33. Dead Air Panels at Shoulder Area inside Lieutenant Flynn's Protective Coat Liner**



**Figure A-34. Dead Air Panels and Elbow Patch inside Sleeve of Lieutenant Flynn's Protective Coat Liner**

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**Figure A-37. Front of Lieutenant Flynn's Protective Pants (Exterior)**



**Figure A-38. Back of Lieutenant Flynn's Protective Pants (Exterior)**

A-20



**Figure A-39. Condition of Left Knee Reinforcement on Lieutenant Flynn's Protective Pants**



**Figure A-40. Condition of Back Left Pocket on Lieutenant Flynn's Protective Pants**

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**Figure A-41. Close-Up of Lower Back Left Leg on Lieutenant Flynn's Protective Pants**



**Figure A-42. Close-Up of Lower Back Right Leg on Lieutenant Flynn's Protective Pants**

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**Figure A-43. Front of Lieutenant Flynn's Protective Pants (Shell Interior)**



**Figure A-44. Back of Lieutenant Flynn's Protective Pants (Shell Interior)**

A-23



**Figure A-45. Close-Up of Charring to Back Lower Left Leg of Lieutenant Flynn's Protective Pants (Shell Interior)**



**Figure A-46. Product Label on Shell of Lieutenant Flynn's Protective Pants**



**Figure A-47. Front of Lieutenant Flynn's Protective Pants Liner  
(Moisture Barrier Side)**



**Figure A-48. Back of Lieutenant Flynn's Protective Pants Liner  
(Moisture Barrier Side)**

A-25



**Figure A-49. Close-Up of Back Lower Right Leg of Lieutenant Flynn's Protective Pants Liner (Moisture Barrier Side)**



**Figure A-50. Close-Up of Back Lower Left Leg of Lieutenant Flynn's Protective Pants Liner (Moisture Barrier Side)**

A-26



**Figure A-51. Front of Lieutenant Flynn's Protective Pants Liner  
(Thermal Barrier Side)**



**Figure A-52. Back of Lieutenant Flynn's Protective Pants Liner  
(Thermal Barrier Side)**

A-27



Figure A-53. Product Label Appearing on Lieutenant Flynn's Protective Pants Liner



Figure A-54. Close-Up of Compliance Label Appearing on Lieutenant Flynn's Protective Pants Liner



**Figure A-55. Inspection Port Opening in Lieutenant Flynn's Protective Pants Used to Invert Liner**



**Figure A-56. Crotch Area Inside Lieutenant Flynn's Protective Pants Liner**

A-29



**Figure A-57. Moisture Barrier Film Side of Liner Interior for Lieutenant Flynn's Protective Coat**



**Figure A-58. Moisture Barrier Film Side of Liner Interior for Lieutenant Flynn's Protective Coat**

A-30



**Figure A-59. Knee Reinforcement on Liner Interior of Lieutenant Flynn's Protective Pants**



**Figure A-60 Seat Area of Liner Interior for Lieutenant Flynn's Protective Pants**

A-31



**Figure A-61. Back Side of Lieutenant Flynn's Protective Left Glove**



**Figure A-62. Palm Side of Lieutenant Flynn's Protective Left Glove**

A-32